The Constitution and Development of the Society of Termites: Observations on their Habits; with Appendices on the Parasitic Protozoa of Termitidæ, and on the Embiidæ.

By

Professor B. Grassi in collaboration with Dr. A. Sandias.

With Plates 16—20.

The memoir, of which I have made the following translation, was originally published in the 'Atti dell' Accademia Gioenia di Scienze Naturali in Catania,' ser. 4, vols. vi and vii (1893–4), but has become more generally known through the appearance of a separate edition in the former year. But though its value was immediately recognised, the work has not yet become familiar to an extent commensurate with the importance of its contributions to natural science.

The object of the treatise, itself an expansion and completion of certain preliminary papers on Termitidæ by Professor Grassi, is set forth in that author's introduction, and requires no further explanation; but it is perhaps permissible to point out that, over and above the results obtained in the pursuit of that object, the memoir is a signal and instructive example of a class of work but too seldom resorted to—the union of morphological research with an inquiry of the most prolonged and persevering character into the habits and bionomics of the living form. In these latter respects it forms a worthy parallel to the work of such great pioneers in the investigation of the social systems of insects as Smeathman, Huber, and Réaumur. And it is for this reason that no study of an abstract which merely summarises the results obtained can prove as convincing or suggestive as that of the original.

An excellent general summary of the various writings on Termitidæ, which includes references to such facts as have been observed since the publication of the present memoir, is to be found in vol. v of the 'Cambridge Natural History,' by Dr. Sharp. In view of its existence it has been thought unnecessary to make more than a very few additions to the original text; these will be found indicated in the usual way by square brackets.

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To Fritz Müller,
on his Jubilee.
Catania, 1892.

Introduction.

It has been recognised by Darwin, in his immortal work on the 'Origin of Species,' that the existence of insect communities, composed of different castes (kings, queens, workers, soldiers, and the like), furnishes his opponents with a trenchant weapon. Now these communities actually consist not merely of fertile forms (kings and queens), but of sterile forms (workers, soldiers, &c.), distinguished by important modifications of structure and marvellous instincts, none of which are to be found in their parents. The sterile progeny would therefore appear to be uninfluenced by one of the prime factors in the struggle for existence, that of heredity, owing to the impossibility of transmitting to the offspring such modifications of structure or instinct as may be gradually acquired; and Darwin himself admits that it required great confidence in his theory not to renounce it in the face of this objection.

I have had to deal shortly with this question on another occasion with regard to bees, for which I have observed that the cause of their apparent deviation from the normal rule may possibly be found in the existence of workers capable of oviposition, which apply themselves to all the tasks of the colony, and possess the characteristics of true workers, with the single difference that they lay parthenogenetic male ova.

The males which hatch from these eggs would then transmit to the female ova—laid, as we know, by the queen—the characteristic properties of the worker.[1]

[1] Darwin, however, explains the phenomenon by a very ingenious comparison. "According to M. Verlot," he writes, "some varieties of the double annual stock, from having been long and carefully selected to the right degree, always produce a large proportion of seedlings bearing double and quite sterile flowers; but they likewise yield some single and fertile plants. These latter, by which alone the variety can be propagated, may be compared

As it is probable that the same explanation is equally applicable to other Hymenoptera, I put aside that order of insects to devote myself to another, of remote relationship—namely, the Corrodentia, of which the Termitidæ constitute the typical form. But I found myself here in a much less cultivated field than that of the Hymenoptera, and it took me several years before I was able to see my way.

In the meantime a school has arisen under Weismann, which denies the heredity of acquired characteristics; this has somewhat modified, and perhaps rendered more interesting the general questions which have inspired my particular researches, as I will explain.

It has been known for many years that the same bee larva may develop either into a queen or a worker in accordance with the nutriment it receives. Nutrition, therefore, possesses a most remarkable influence on the bee's generative organs, and on many other characters correlated with their greater or less development (e.g. the faculty of producing wax, or of collecting honey, which is possessed by the worker only, and not by the queen). This would indicate that the environment has a powerful and direct influence on the genitalia, and would therefore tend indirectly to show that the much-disputed inheritance of acquired characteristics is a possibility.

with the fertile male and female ants, and the double sterile plants with the neuters of the same community. As with the varieties of the stock, so with social insects, selection has been applied to the family, and not to the individual, for the sake of gaining a serviceable end." ['Origin of Species,' ed. 6, p. 230. The whole chapter should be consulted.] But it may be objected that the difference between the queen and worker forms is far more profound than that between the simple and double stocks.

Büchner ['Aus dem Geisteslebens der Thiere,' translated under the title 'Mind in Animals,' London, 1881], on the other hand, thinks that the explanation of the phenomenon should be found partly in atavism, and partly—as far, that is, as regards the marvellous instincts—in the instruction which the young receive from the colony. That atavism certainly plays a part in instinct is demonstrated *ad evidentiam* by a fact discovered by myself. It is known that certain silkworms become pupæ and moths without spinning a cocoon. Now my experiments show that the offspring of such moths may spin perfectly constructed cocoons.

But this argument in its favour would be greatly weakened if the circumstance indicated by me above—namely, the possibility of hereditary transmission by means of oviparous workers—should have played the part which I suppose it to have done.

I determined, therefore, to investigate the origin of the workers and soldiers in Termitidæ,—in forms, that is, whose phylogenetic source is certainly absolutely distinct from that of the social Hymenoptera.[1] Such an inquiry would at least throw light on my hypothesis with regard to the bee, and in any case should lead to results of some utility for the problem I have several times referred to, the heredity of acquired characteristics, and for the subordinate and related question of the direct influence of environment on the generative organs.

The recent researches of Van Beneden, Boveri, O. Hertwig, and others on the ovum and spermatozoon had afforded yet another problem for solution, which would be modified according as to whether there should or should not exist special eggs or spermatozoa for the workers and soldiers of Termitidæ.

In short, the theory of evolution, the disputed heredity of acquired characteristics, and lastly, the theory which postulates the existence in every somatic cell of elements derived from both parents, these alike have all furnished me with motives for regarding the elucidation of the origin of caste forms in the social Termitidæ as a problem of the highest interest. This, then, is the main object of the present memoir, and it has been arrived at only by dint of prolonged observation and preliminary experimentation, the results of which are fully related here as a necessary corollary.

The development of my argument has, so to speak, com-

[1] It must be recollected that, though we are acquainted with forms which perhaps can be ascribed to the Blattidæ from the Silurian strata, the Termitidæ, according to Scudder (in Zittel's 'Handbuch der Paläontologie,' ii, 772), are absent in all the palæozoic, and appear only for the first time in mesozoic strata. Nevertheless the phylogenetic independence of the Termitidæ and Hymenoptera is indisputable.

pelled me to discuss neoteinia[1] and the simplification and degeneration of forms, and therefore to express my present views on the Thysanura, which for a long time formed the special object of my studies.

In these preliminary remarks I have prominently set forth the fundamental ideas which have directed my work, and now pass at once to the consideration of the Termites.

As yet two species only of Termitidæ, Calotermes flavicollis, Fabr., and Termes lucifugus, Rossi, have been found in Italy. The latter forms the subject of Lespès' admirable monograph,[2] but Calotermes flavicollis is known to us only by a few accounts of merely systematic importance, and not even complete.[3]

However, Fritz Müller has made important investigations[4]

[1] [The term neoteinia has been introduced by Camerano ('Bull. Soc. Ent. Ital.,' 1885, pp. 89—94) to denote the persistence during adult life of part or all of the characteristics normally peculiar to the immature, growing, or larval stages (*e.g.* the persistence of gills in the axolotl). It therefore covers much the same ground as is denoted by the term pædogenesis, but appears, so far as can be gathered from Camerano's paper, to include a somewhat wider class of facts than those comprised under the latter term, which would fall under his definition of total as opposed to partial neoteinia. Neoteinia, or the persistence of larval characteristics, does not necessarily imply that anticipation in time of sexual maturity which is usually connoted with the use of the term pædogenesis,—which, moreover, is strictly applied to agamic reproductions.—W. F. H. B.]

[2] "Recherches sur l'organisation et les mœurs du Termite lucifuge," 'Ann. Sci. Nat.' (4), v (1856), pp. 227—282, pls. v—vii.

[3] [Hagen, "Monographie der Termiten," 'Linn. Entom.,' x, 1—144, 270—325; xii, 4—342. The reference to C. flavicollis, op. cit., xii, pp. 54—61, pl. i, fig. 12; pl. ii, fig. 15.]

[4] "Beiträge zur Kenntniss der Termiten," 'Jen. Zeitschr.,' vii (1873). I. "Die Geschlechtstheile der Soldaten von Calotermes," pp. 333—340, pls. xix, xx. II. "Die Wohnungen unserer Termiten," pp. 341—358. III. "'Die Nymphen mit kurzen Flügelscheiden' (Hagen), 'Nymphes de la deuxième forme' (Lespès). Ein Sultan in seinem Harem," pp. 451—463. Id., ix, 1875. IV. "Die Larven von Calotermes rugosus, Hag.," pp. 242—264, pls. x—xiii.

on another species of Calotermes, and these, as will be seen later, are in entire agreement with our observations on the European species.

Nevertheless, as I have already mentioned, the study of Termitidæ in general is as yet very incomplete; and although books of travel certainly abound in notices of these interesting insects, they mostly deal with detached and imperfect observations.

I have repeated Lespès' investigations on Termes lucifugus with particular reference to the so-called "nymph of the second form" which that distinguished naturalist described.

He attributed to it an entirely different significance from that which it really possesses, owing mainly to the circumstance that his period of study was confined to about nine months—from November, 1855, to August, 1856. But how difficult the elucidation of the true function of this nymph of the second form has been the reader will gather from the pages of this memoir; and I may state at once that it has necessitated the removal of many hundred cubic metres of earth and the cutting up of hundreds of trees, a task that has had to be carried out little by little, and has consequently demanded no small amount of patience.

I am indebted to a small but fortunate discovery for the most interesting observations on Calotermes flavicollis, which I have to relate in the present work.

If from three to twenty Calotermes of different ages are placed in a glass tube three to eight centimetres long (Pl. 19, fig. 11), closed with a cork and kept warm—for example, in the waistcoat pocket, unless in summer-time, they continue to live and constitute a family, or better, an independent colony; they rear a fresh king and queen,[1] if orphaned, and they rear soldiers,

[1] [The statements made on the sexual forms of Termitidæ will be more clearly understood if anticipated by a summary and definition of the terms employed in the course of the work. Sexual or royal forms are of two kinds, true and neoteinic. The true royal forms are imagos, or perfect insects, which acquire a complete development of the wings and

&c., if in want of them. In short, after a certain time the tube will contain a complete little nest, if it did not originally do so. However, the insects do not hesitate to bore through the cork, and, unless they are watched, one is surprised to find some day that they have all made their escape. But frequently they remain in the tube, even though they have made holes putting them into communication with the outer air (Pl. 19, fig. 11).

Some of these little nests can be kept alive for several months, but many die off after a few weeks, though not until they have afforded sufficient opportunity for making numerous observations through the glass walls by aid of a lens. It is desirable to use tubes of various lengths and calibres, because certain points are better seen in a wide than in a narrow tube.

In addition to the insects, the tubes are partly filled with fragments of wood, which should be neither too dry nor too moist. In the former case the insects gradually shrivel, contract, dry up and die; and in the latter case there is a deposit of water vapour on the inner walls, and they are evidently killed by over-dampness. Death ensues more or less rapidly according to the amount of water deposited, and is sometimes almost as sudden as if the insects were suffocated or chloroformed. Slow death due to over-dampness may be accompanied by distinct œdema or reddish discoloration of the

darkening of the chitin concomitantly with the maturation of the gonads after the last ecdysis. They leave the nest by "swarming." The neoteinic royal forms undergo a premature maturation of the gonads whilst in a late larval or nymphal instar, or that of an immature and pallid imago. This maturation is accompanied by an arrest of development of other parts of the body; the chitin does not darken normally, and the wings do not grow further. They do not leave the nest. The latter class is further subdivided into complementary and substitute royal forms. Complementary forms are not found in Calotermes, but are normal components of the Termes nest, in which they are the only reproductive individuals. Substitute forms are developed to supply the loss of the true royal forms in Calotermes, or the complementary royal forms in Termes. The three varieties of royal examples all comprise kings and queens,—that is, individuals of each sex.]

body; the latter is accompanied by the presence of a bacterium which I have not investigated.

If the wood is too damp the colony may generally be saved by the simple precaution of leaving the cork out of the tube; after a few days the moisture diminishes, and the cork must then be re-inserted, or the opposite extreme of undue dryness is quickly reached. With time and patience an exact estimate can be formed of the amount of moisture necessary, and it can then be easily regulated. The cork must fit closely, and want of oxygen need not be feared. At one time I was accustomed to uncork the tubes three or four times a day, but I subsequently found this to be quite unnecessary; if the Calotermites require change of air, they are able to provide it for themselves by boring through the cork.

When these tiny nests are examined the tube may conveniently be laid flat and left quiet, but an occasional shake is sometimes useful to rouse the inmates to activity.

Unfortunately Termes lucifugus does not flourish in these tubes, but drags on a feeble existence for a week or ten days at most; I have made many but quite unsuccessful attempts to establish a moderately suitable environment for them therein. The species is all the more difficult to study because, in comparison with Calotermes, the members of a colony are smaller and more rapid in movement.

Many as have been the details made out through these glass tubes in my laboratory, there are others which will be more successfully undertaken by anyone who has the opportunity of applying my method to the large exotic species.

Considering that the termites of tropical countries are among the most injurious of insects, I must point out a practical result of my investigations, and one of the highest importance. Contrary to the belief of residents and the accounts of travellers, such as Major Casati,[1] a nest of termites cannot be destroyed merely by killing the king and queen. If there remain alive some eight, ten, or twenty examples, which include any undifferentiated larvæ, or larvæ of perfect

[1] ['Ten Years in Equatorial Africa,' i, p. 165.]

insects or nymphs, these eight, ten, or twenty will form a new colony, which slowly but surely will become as flourishing as the original stock.

It follows, therefore, that the extirpation of these insects is excessively difficult in practice; and their entry into any situation where they can prove destructive must be prevented. This is the strategy to adopt against them, for when once they have gained admission there is no way of getting rid of them.

The present work has no claim to be a complete monograph of the Termitidæ, and merely furnishes materials for whomsoever will undertake so large a task. It is confined, in short, to the discussion of certain fundamental points.

Before concluding I must express my thanks to Dr. Calandruccio, who has given me no little help in this research. Many observations, particularly those on Calotermes kept in tubes, have been made under my supervision by my pupil Dr. Sandias, and have afterwards been carefully verified by myself.

The Colony of Calotermes flavicollis.

1. Situation and Nest.

As with all Termitidæ, the life of Calotermes is intimately connected with the vegetable kingdom, for it lives exclusively on woody matter. At Catania I have found it only in the stems or roots of living but partially decayed, and therefore, as a rule, old plants, and never in those of which the stem or tap-root measures less than one or two centimetres in thickness. But when once established in a stem or main root it can extend into decayed portions of the branches or side-roots, even if of lesser diameter. Though always absent in entirely sound plants, it can be found in partly decayed examples of many kinds,—of many, but not of all, for I have never met with it in lemon, orange, or Agave americana, &c. It is also relatively scarce in cactus (Opuntia), even though large portions of the plant are dead; but if present, it may infest

the rotten phylloclades, which in fact are sometimes the first portions to be occupied.

It is difficult to find a tree with any decayed portion which has not been attacked by Calotermes in Catania and the adjoining provinces, at least in the low country, for I have not searched at a higher elevation than Nicolosi. At Castrogiovanni the species appears to be entirely absent.[1]

As mentioned above, it inhabits still living plants. Should the plant die the Calotermites survive until it has become completely dry, when they perish—a fact that anyone can verify by examination of the vine-stocks annually turned out from old vineyards. If the dead trunk does not dry up, as is the case in marshy situations, the insects continue to flourish.

Lucas and some other writers state that they have found Calotermes flavicollis in buildings. I have never observed this at Catania, but Dr. Sandias has found flourishing colonies at Trapani in the woodwork of verandahs, doors and stairways, &c., ten years old; probably the wood harboured the insects before being worked up for domestic purposes. It should be observed that the climate of Trapani is very damp, so that wood probably dries less there than at Catania.[2]

In order that a plant may harbour Calotermes, it must (necessarily), as I have stated, exhibit some amount of decay, because such decayed portions alone are occupied. To proceed to details, Calotermes never invades the healthy parts, but encroaches at most on their boundaries. If a partly decayed vine-stock is infested, it is usually easy to make out that the healthy tissues are respected; yet should they contain an internal channel of decay barely larger than the body of a Calotermite, the insects can enter and excavate a gallery, which will then present but a very thin lining of decayed matter, and

[1] [In a foot-note at the end of the original work the authors state that, since it was printed, Signor Giuseppe Corona has discovered the species at Castrogiovanni.]

[2] The Marchese Doria informs me that he has confirmed Dr. Sandias's observation at Genoa, although the climate there is certainly not moister than that of Catania.

will therefore appear to run in the sound structures. But, so far as I have observed, this lining of decayed tissue is never absent.

It is undeniable that the process of decay is hastened by these burrows, particularly because they allow the infiltration of rain-water; but a detailed study of these phenomena would lead too far from the subject.

Calotermes greatly prefers to live in the deepest parts of the dead wood,—that is, the parts nearest the living tissues, and consequently the most recently decayed. Portions which have been long dead are usually too dry for it, and are chosen as a tenement by ants.

Fertile pairs, unaccompanied by eggs or with very few offspring—that is to say, nests in process of formation or recently formed,—are to be found by special search at the places where a plant has been pruned a year or two previously and has subsequently rotted, provided that the pruning has not followed on antecedent decay. This can be easily observed in the fig or vine. Fresh nests, therefore, are usually established where the dead portion is still so limited in extent as not to afford space for a numerous colony, and these situations are rarely preoccupied by other insects, such as ants, beetles, or other Termitidæ, &c. As the colony gradually increases and requires more room, the decayed area spreads, but to all appearance independently of the insects. That this is the case is rendered probable by an examination of progressive decay in a district where Calotermes is absent, such as Lombardy, where the winter is too severe for them.

Turning once more to the formation of the fresh termitaria, I do not wish to deny the possibility of its taking place in trunks in which extensive decay already exists; but such an occurrence is unusual, either because the wood is preoccupied by termites or other insects, or because the royal pairs must traverse parts which are already dry and swarming with enemies (ants), in order to arrive at the required spot where the decay is most recent.

The corks of the tubes are attacked probably because they

retain a certain amount of moisture; for if the insects are shut up with nothing but particles of cork they all die in a few days.

To sum up, two conditions are essential for the life and well-being of Calotermes—a suitable temperature and a suitable amount of moisture. But whereas increase of temperature is favorable, at least up to a certain point, the degree of humidity can vary only within very restricted limits.

Owing to the severity of the winter, Calotermes is absent from Lombardy, Piedmont, and Venetia, but it is found in the province of Genoa; its northward distribution is not accurately known. At Catania it is much more sluggish in winter than in summer, the ova do not develop, and the larvæ and nymphs do not moult. The influence of moisture has been repeatedly referred to; it is correlated with the nature of the cuticular structure (chitinous layer), which except in a few regions, such as the mandibles, is very thin, even in the adults and royal pairs, in both of which it is brown in colour. The younger the individual, or the more recent its ecdysis, the thinner is the chitin. In general the rule holds good for Calotermes that white and semi-transparent examples have a thinner cuticle than those which are more opaque and inclined to yellow (very old soldiers or substitute-queens). Young or freshly moulted specimens, usually distinguishable by their greater transparency and whitish or rarely faintly yellow colour, always require more moisture than those which are older or have not cast their skin for some time, and possess a more or less evident yellow tint. The imagos, before or after the loss of their wings, can endure a greater degree of dryness; but even these generally die in a short time if removed from the wood and exposed to the open air.

These conditions of temperature and moisture, naturally with some variation in degree, especially of the latter factor, must hold good for all other species of Termitidæ, and are probably correlated with their limitation to warm countries, their much wider European distribution in epochs when the mean temperature was presumably higher, and with their

choice of evening or night, the interval after a shower or a wet day as a swarming-time (Casati).[1]

The nest of the Sicilian Calotermes resembles those of its congeners, which show, as a rule, very little architectural skill. Strictly speaking, they do not build any nest, but content themselves with burrows excavated in wood and never quitted. These burrows vary very much in dimensions, and the same gallery may be narrow in one part and very wide in others. In one of the enlargements, towards the heart of the nest, the royal couple, with a numerous surrounding, is usually to be found. There is never a true royal chamber, such as has been described for many other species. The galleries are very variable in direction, but the widest and longest are generally subparallel with the long axis of the stem. A large number of transverse passages is commonly found, and these are often too narrow to allow room for more than a single individual at a time. According to Fritz Müller,[2] the burrows of Calotermes possess an inner lining of excrement. This appears at first sight really to be the case when they are excavated in rotten and somewhat softened wood. But if they are examined in cork, or in wood which, though dead, is still hard, the absence of such a lining is easily established, and this fact once determined, one can satisfy oneself that burrows made in damp wood are also unlined.

In common with other termites, Calotermes avoids the outer layers of the cortex (as may be readily observed in vine-stocks), and thus protects the nest from the direct action of the atmosphere or infiltration of water.

As previously stated, the colony provides for an increase in numbers by penetrating deeper into the wood. This penetration is also determined by the fact that the superficial wood becomes too dry. The abandoned portion becomes then commonly occupied by ants, the pitiless enemies of Calotermes. The termitarium is separated from the ant-burrows, or from openings caused by wind-cracks or axe-wounds by means of

[1] ['Ten Years in Equatorial Africa,' i, p. 166.]

[2] ['Jen. Zeitschr.,' vii, p. 343.]

barricades of masticated wood, or more commonly of excrement, which is cemented together by saliva, with or without an admixture of disgorged wood. This disgorgement is normal, and not exceptional, as Fritz Müller believes.[1]

The following facts and other details of interest may be easily observed through the glass tubes.

If some fragments of wood and a few Calotermites are put into a tube and left uncorked, the insects will be found on the following day to have established themselves either in the whole of the space filled with wood, or in its lower portion, at the bottom of the tube. In either case the occupied area is delimited by means of disgorged matter deposited in the interstices between the particles of wood. As far as can be seen the boundary wall is complete, but it lies at different levels and not entirely in the same plane; its margin can easily be made out at the point of contact with the glass, and will be found on revolving the tube to form a complete circle, but with some irregularities of level, obviously due to a selection of the smallest interstices for cementing up without reference to their higher or lower elevation.

[The process of construction can be watched in the tubes; the insect regurgitates a pasty mass, which is spread out, if necessary, by the antennæ, so as to form a rounded pellet on the glass of about a millimetre in diameter, and of the colour of rotten wood.]

The boundary wall is undoubtedly designed for protection against direct contact with the atmosphere; this is proved by its not being constructed if the tube is closed with a cork instead of remaining open.

Such a wall may occasionally be built even in a corked tube, should part of the nest contain any offensive substance. Thus if flour be added to a small tube-nest, after a few days the upper part containing the flour, which will have become mouldy, is found to be cut off in the manner described from the lower portion, in which all the insects have collected.

Sometimes the Calotermites in a tube may be seen to cement

[1] ['Jen. Zeitschr.,' vii, p. 343.]

together pieces of wood which are unduly loose; but at other times they do not do so, although much incommoded by their mobility. In certain cases they line the lumen of the tube with disgorged matter, so as to form a continuous layer, save for a few irregular patches, but they generally spare themselves this task, or merely begin and immediately abandon it.

It should be added that if the tube is too damp its inner surface may be covered with moisture, to which the insects adhere, particularly when young, and so die. This is guarded against, at least partially, by the lining of disgorged substance.

When the supply of wood in the tube is very small, the Calotermites usually have recourse to the cork, in which they bore one or more galleries a little wider than their body; they gnaw away and hollow out the cork, carrying the débris into the tube, which is soon filled up, as the cork-dust is allowed to remain as a loose mass.

If a corked tube is surrounded with sawdust, some of it can generally be found in its interior, having been carried in through galleries in the cork but little wider than the insects' bodies.

[The corks of tubes kept in the waistcoat pocket are often channelled with burrows leading to the exterior, through which the insects escape and are lost, in the belief that they are enlarging their nest. Sometimes books near which the waistcoat was laid at night were attacked, and the paper was found to be gnawed in places the next morning.]

Burrows made in corks may often be seen to possess a sort of rounded lid at their external opening; this is cut out of the superficial layer of cork, and fits tolerably closely, though it usually falls in a little. It may be hinged to the cork by a more or less wide attachment.

[Calotermites may be frequently seen to carry excrement to the bottom of the tube, and to accumulate it there, mixed up with wood and cork-dust; and sometimes they keep the eggs in the same place.]

If the stopper is too narrow the space between it and the tube is gradually filled up with excrement.

Calotermes flavicollis differs materially from Termes lucifugus in the fact that it confines itself to excavating burrows, and is thus merely a borer; whereas the latter species not only bores, but builds tunnels, in order to connect pieces of wood at a considerable distance apart.

2. Number of Individuals in the Colony.

In these observations a normal development of the colonies is assumed. For should the queen, for example, die before the community has reared a successor, several months pass during which oviposition is suspended and multiplication is consequently brought to a standstill.

A colony of Calotermes rarely consists of more than a thousand members, and is relatively numerous when it contains five hundred. This is correlated with the fact that the queen of our species is very far from attaining the colossal dimensions which are well known to occur in the queen-termites of tropical countries.

After fifteen months of common life the king and queen may be surrounded with fifteen or twenty young, after another year with about fifty, and in the two or three following years the population increases till it reaches a maximum at which it becomes nearly stationary. This is attained when the king and queen have reached the largest possible size.

Eight or ten winged adults may depart from a two-year-old nest, and the number leaving in successive years increases concomitantly with the increase in the population.

At the time of maximum oviposition a queen of three to four years old lays as a rule four, five, or six eggs a day.

3. The Different Castes (Plate 16).

By way of preliminary, it should be stated that for the sake of orderly arrangement a knowledge is assumed in this part of the work of certain conclusions, the demonstration of which is postponed to the succeeding chapter.

A colony of Calotermites contains—

1. Undifferentiated larvæ (fig. 1), capable of becoming

either soldier larvæ, or larvæ of perfect insects,—that is, larvæ possessing the first indications or rudiments of wings.

2. Larvæ of perfect insects (fig. 3), and nymphs (fig. 4) derived from them.

3. Larvæ of soldiers (fig. 2), and soldiers (figs. 5 and 16); the latter derived from the former, and those derived from undifferentiated larvæ, from the larvæ of perfect insects, or from young nymphs.

4. Perfect insects derived from nymphs (fig. 6).

5. A royal couple, properly so called, derived from perfect insects (figs. 7—11).

6. Larvæ of substitute royal forms (fig. 14), and substitute forms (figs. 12, 13, and 25) themselves derived from the former; those in their turn having originated from undifferentiated larvæ with fourteen or fifteen antennal joints, from larvæ of perfect insects, or from nymphs.

To proceed to details: a colony contains newly hatched larvæ about 1 mm. in length,[1] with ten antennal joints of which nine are pilose, and one not. The glabrous third joint is relatively very long, and presents indistinct traces of a tripartite division. These traces soon become more marked, and the separation of the distal joints appears constantly to be clearly defined before that between the middle and the proximal joints, and possibly may actually precede it.

As a result we have larvæ which are a little over 2 mm. in length, and exhibit twelve distinct antennal joints, of which the 3rd, 4th, and 5th are short and bare. In succession the 5th joint, as far as I have seen, becomes pilose and relatively longer; then the 4th and finally the 3rd exhibit the same phenomena.

We thus obtain examples with twelve antennal joints, all pilose; and in the meantime the body increases in size, so that such specimens measure about 4 mm. in length.

The newly born larvæ are all perfectly alike,—that is, they

[1] In Termitidæ the length of the individual as a rule has only a relative value, as it depends largely on the degree of moisture in the atmosphere, the food supply, &c.

are undifferentiated; but when they have attained an average length of 2 mm. they are divisible into two groups, one with a large head, little narrowed anteriorly (Pl. 16, fig. 2), the other with a small head, more evidently narrowed towards the apex (Pl. 16, fig. 1).

The former have become soldier larvæ, and will ultimately become soldiers. The latter are still undifferentiated; they reach a length of 4 mm. and acquire twelve pilose antennal joints (vide supra); the character of the head either remains unchanged, and continues to be undifferentiated, or becomes modified by an increase in size and in the width of the anterior portion, so that they become soldier larvæ.

Small soldiers (Pl. 16, fig. 16) are to be found which are derived from these very larvæ; they are less than 5 mm. long, and possess twelve pilose antennal joints, with an ill-marked suture between the 4th and 5th.

It may be well to observe at once that soldiers of medium size with thirteen or fourteen pilose antennal joints, and large soldiers (Pl. 16, fig. 5) with fifteen to seventeen pilose antennal joints also exist. Further, the antennæ of many soldiers are evidently mutilated.

Moreover I have often found soldiers with antennæ of twelve, thirteen (Pl. 16, fig. 19), or fourteen all pilose joints, of which the third is in process of division into two, both pilose; sometimes the division is completed in one antenna and hardly indicated in the other. In short, all intermediate stages exist between small, medium-sized, and large soldiers, and the foregoing distinctions have therefore a relative value alone.

For a considerable time I supposed that the soldier of medium size originated from the small soldier, and grew itself into a large soldier; but as I have not succeeded in proving my hypothesis, in spite of long-continued research, I can no longer consider it to be well founded.

Turning to the undifferentiated or small-headed larvæ, we have already seen that they can acquire antennæ of twelve entirely pilose joints, and a length of 4 mm. Subsequently a thirteenth joint is added, and their length increases to 6 mm.,

when also the thirteenth joint becomes pilose; then a fourteenth joint is developed, and the whole fourteen are always found to be pilose in examples of 7 mm. and upwards in length.

Examples with fourteen joints may exhibit evident traces of wings, which indeed may be already present in individuals with thirteen pilose joints, and a very indistinct rudiment of a fourteenth glabrous joint at the base of the third. But, on the other hand, examples with fifteen joints may be found without trace of wings.

Those which have acquired wing-rudiments may be called larvæ of perfect insects.

Undifferentiated larvæ, with thirteen or fourteen joints, as well as larvæ of perfect insects with thirteen (the fourteenth very imperfect) or fourteen joints may undergo a direct transformation into soldier larvæ with thirteen- or fourteen-jointed antennæ, and from these originate the soldiers of medium size with the same number of antennal joints.[1]

Lastly, undifferentiated larvæ with fourteen joints may either become larvæ of perfect insects without increase in that number, or they may remain unchanged till it has been increased to fifteen, all of which are pilose; and the latter condition may also be reached without change by the larvæ of perfect insects.

Both the undifferentiated larvæ and those of perfect insects with fifteen joints may give rise, without increase in that number, to the same kinds of forms that have been indicated for the larvæ of fourteen joints,—soldier-larvæ, larvæ of royal substitutes, and, provided that they are as yet undifferentiated, larvæ of perfect insects; and the last may acquire a sixteenth joint without increase of the wing rudiments (Pl. 16, fig. 3). As a rule, therefore, the development of the sixteenth joint is accompanied by an increase in the wing-rudiments, so that the larva of the perfect insect becomes a nymph.

I have found no undifferentiated larva with more than fifteen antennal joints; but, as I have said, we may have sixteen

[1] I have been unable to decide whether the number of joints is capable of increase in the soldier larvæ.

completely pilose joints in the larvæ and nymphs of perfect insects. During this stage both of the latter may undergo the same fate as in the preceding stages, becoming soldier larvæ, larvæ of substitute royal forms, or, if already larvæ of perfect insects, nymphs.

Both the larvæ of perfect insects or nymphs may pass without change to the stage in which the antennæ possess seventeen joints. During this stage both may become larvæ of soldiers or royal substitutes. If this does not happen the nymphs acquire larger wing rudiments, and the larvæ of perfect insects become nymphs (Pl. 16, fig. 4).

Before proceeding further it is desirable to give a fuller definition of the term nymph.

It may be applied to such examples as are 8 or 10 mm. in length, with sixteen or seventeen antennal joints, and with wing-rudiments easily distinguishable by the naked eye. The expression, it must be observed, is incapable of precise definition, inasmuch as there are no characters in insects with an incomplete metamorphosis which distinguish a larva from a nymph, except the wings, which have already begun to develop in larvæ of a certain age. It might possibly be adopted as connoting the earliest rudiments of wings, but this presents the difficulty that they are not easily detected. I therefore follow the terminology of Lespès and Hagen, and conventionally indicate as nymphs those individuals which have the beginnings of the wings readily visible to the naked eye.

From the account just given it follows clearly that large soldiers are derived from the large soldier larvæ, just as the moderate-sized and small soldiers originate from larvæ of corresponding sizes, and that the large soldier larvæ have arisen in their turn from undifferentiated larvæ with fifteen antennal joints, or from larvæ of perfect insects with antennæ of fifteen, sixteen, or seventeen joints, or lastly also from nymphs. The latter, possessing sixteen or seventeen joints, may be transformed into soldier larvæ, and subsequently become large soldiers in which the wing-buds can be distinctly made out with the naked eye (Pl. 16, fig. 26). At a later period these

rudiments are reabsorbed until hardly a trace is discoverable with the microscope. This origin of the soldier from the nymph is certainly infrequent.

Nymphs with seventeen antennal joints may become imagos without increase in that number, or with an antecedent addition of one or even two joints; and the perfect insects may thus exhibit antennæ with from seventeen to nineteen pilose joints, a numerical difference which has no relation to sex. Nymphs with seventeen to nineteen joints may be also transformed to royal substitute larvæ, but I do not believe that those with eighteen or nineteen joints can become soldiers, as I have never found so large a number in any example of that caste.

The change from the nymph to the imago is accompanied by the development of pigmented compound eyes, while the wing-rudiments, from being vertical and closely appressed to the sides of the body, become dorso-lateral at their origin, nearly horizontal, and divaricate at the apex.[1] These specimens have at last reached the adult stage (imago), and (Pl. 16, fig. 6) possess fully developed wings; at first white, they gradually become black and capable of flight.

It will be seen from this account that examples with a number of antennal joints varying from twelve to seventeen, and therefore of very different lengths, can be transformed to soldier larvæ, and consequently to soldiers; and that those in which the number of joints varies from fourteen to nineteen may become larvæ of substitute royal forms. The latter larvæ are not easily separable from the others; but in those with from fifteen to seventeen antennal joints the pigmentation of the compound eyes is evident. But it is absent or very scanty in substitute larvæ with fourteen, and some with fifteen joints. Ocular pigment is sometimes present in nymphs with seventeen, and always in nymphs with eighteen or nineteen antennal joints before their metamorphosis into substitute royal larvæ.

The larvæ of perfect insects or young nymphs are customarily selected for development into substitute forms (Pl. 16, fig. 14),

[1] In these specimens the wings have really reached their full development, but are enclosed in a chitinous sheath.

and the wing-rudiments of the resulting royal examples are therefore absent or very ill-developed. [When a nymph with more evident wing-rudiments is selected for the throne, one or more of these (usually that of the right fore-wing) is bitten off (Pl. 16, fig. 18)].

I have repeatedly stated that the royal forms may originate in two ways; in one case they are derived from perfect black examples, of which the wings are fully developed and become detached along a special line of fissure, so as to leave a short stump (the Schuppe or Squama of authors). These examples constitute the true black or normal kings and queens. In the other case the royal forms are substitutional, and originate from examples which have suffered an arrested development of the wings, and in which the compound eyes are usually but not invariably pigmented[1] (Pl. 16, figs. 17, 25). It is remarkable that the antennæ are never found intact in any king or queen, whether true or substitute, however young it may be. And the majority of royal forms possess a different number of joints, varying from thirteen to six or even four on either side.

A most striking feature of the Calotermite colony is the entire absence of workers, in which this species agrees fully with the American form studied by Fritz Müller.

It may, therefore, be concluded that the kingdom of Calotermes is composed of three castes: that of the soldiers; that of individuals which reproduce without becoming black imagos; and lastly, that of forms which lay eggs after the acquisition of fully formed wings,—that is, after reaching the stage of the perfect insect.

The phenomena related in this section may be recapitulated in the following synthesis.

The normal development of Calotermes up to the perfect stage may undergo deviation at different

[1] Perfect insects which are still white may also become substitute forms. They do not darken, and the wings are torn off, rarely along the special line, but usually irregularly as in Termes lucifugus (q. v.). These observations were made after the present work was completed.

ages. This deviation may lead to the formation of substitute royal forms, or of soldiers, after passage through the respective larval stages. The soldier larva may originate by modification of examples with from twelve to seventeen antennal joints; and the larva of the royal substitute forms by modification of examples with from fourteen to nineteen antennal joints. Perfect insects which are still white may also become substitute forms.

I can confirm the fact discovered by Lespès[1] in Termes, and by Fritz Müller[2] in Calotermes, that the caste of soldiers is composed of examples of both sexes.

A minute description of all the forms in the different stages of development would be of little interest, and I shall therefore confine myself to a few points which have a special bearing on the problems I have undertaken to solve.

Beginning with the sense-organs:

(1) All trace of eyes is wanting in newly hatched larvæ. The soldiers possess compound eyes, unpigmented and not prominent. The time of their appearance has not been determined; they are present in a rudimentary condition in larvæ of 3—4 mm. in length, with twelve antennal joints—the third glabrous, but they are not clearly distinguishable except in sections. At a later period they are evidently faceted, but remain destitute of pigment. The compound eyes acquire pigment, as previously mentioned, in nymphs about to become imagos and in most examples selected for the dignity of substitute kings or queens. In the perfect insect the eyes become more prominent and abundantly pigmented, and between them is developed an ocellus devoid of any trace of pigment, which I therefore regard as rudimentary.

(2) Sensory hairs (Tastborste), characterised by their shortness and their connection with the nervous system, are very abundant over the antennæ and the whole of the mouth

[1] 'Ann. Sci. Nat.' (4), v, p. 244.

[2] [Jen. Zeitschr.,' vii, pp. 333—340.]

parts, which possess no other, form of nerve-ending, such as cones (Kegel) or papillæ (Zapfen). These hairs are especially numerous on the apex of both pairs of palpi and on the antennæ; on the latter they are most abundant on the apical half of the terminal joints. There appears to be no marked difference between the sensory hairs of the mouth parts and antennæ, and experiment shows that the latter organs are constructed so as to remain functional even when deprived of a certain number of joints.

(3) The tibiæ exhibit the peculiar sense-organs discovered by Fritz Müller,[1] evidently tympanal organs (Pl. 19, fig. 10).

This is shown by the presence of the usual terminal rods, of a characteristic tracheal branch, the lumen of which is not accurately cylindrical, and which opens at either extremity into the main tracheal trunk of the tibia, and lastly, of tympanic membranes.

Tactile hairs are present on various parts of the body, and the so-called abdominal appendices (cerci) also appear to be essentially tactile. These appendices are really identical with the caudal cerci of Thysanura, reduced to a short basilar piece and a long terminal joint, of which the apical extremity is glabrous. The remainder of their surface is covered with very long, fine, and readily vibratile hairs, in addition to others, such as are scattered over the body.

The description just given of them goes to show that they correspond in Calotermes with those found in other insects. All the sense-organs here described, with the aforesaid exception of the eyes, are fully developed at the time of hatching. The visual structures are certainly more or less imperfect except in the adults, and become functional concomitantly with the wings. Their unimportance in other stages is evident from the fact that pigment may be either present or absent in the eyes of substitute royal forms, and that individuals without, or with more or less imperfect eyes, apply themselves equally well to the work of the colony.

[Calotermites move their antennæ freely, and employ them

[1] ['Jen. Zeitschr.,' ix, p. 234, pl. xii, figs. 32, 34.]

just as a blind man does his stick, as Lespès observes. But they are not accustomed to use them in mutual caresses, like other social insects. If the antennæ are cut off at the base the insect becomes inert, stands in a fixed attitude, almost disregards the difference between light and darkness, quivers (vide infra) at rare intervals, and then for a shorter period and less violently than usual. It is not successful in soliciting excrement (vide infra), or does not directly attempt to do so. All these inconveniences are only partially exhibited if the antennæ are detached more or less remotely from their base.]

Fritz Müller's observation[1] that the number of antennal joints in Calotermes rugosus is increased by the successive formation of new joints at the base of the third is well known, and has led to the division of the antenna into two components (base and flagellum), as in other Arthropoda.

I have attempted to determine the origin of the new joints in Calotermes flavicollis, but have not been successful in obtaining a clear idea of the process.

In deciding whether any given joint is the most recent, its smallness, its freedom from hairs, and the indistinctness of the line of demarcation between it and the parent joint must be taken into account. But it will be readily understood that all these criteria are apt to fail.

In the present case, the one which appears most practicable (the presence or absence of hairs) may certainly lead us astray. In fact, antennæ of 13, 14, 15, 16, and 17 joints, with the third and fourth joints glabrous, are to be found, as well as completely pilose antennæ of twelve to sixteen joints (fig. 22). The natural inference is that the third or fourth joint, which was pilose in the latter examples, has become denuded in the former (e.g. for an antenna of fourteen joints, the 3rd and 4th pilose, to become fifteen-jointed (fig. 21) with the 3rd and 4th hairless, one or other of the latter joints must necessarily have lost its clothing) ; this may have taken place in connection with ecdysis, as we shall see later.

[1] ['Jen. Zeitschr.,' ix, pp. 246, 247.]

The broad fact remains that individuals exist with from thirteen to seventeen antennal joints, with either the third or fourth (fig. 20) or both joints glabrous, or without a single glabrous joint.

How are the new joints formed? I regard it as certain that the 13th arises by unequal division of the 3rd, at the base of which it appears as a bud. The 15th and 17th appear to arise from the 4th, and the remainder like the 13th (Pl. 16, figs. 20—22). But closer study is necessary before arriving at a conclusion.

It is of fundamental importance to notice that the new joints do not take origin from a zone of embryonic (undifferentiated) tissue, but from already differentiated structures (hypodermis, nerves, &c.).

Calotermes moults periodically, and it is quite untrue that the number of antennal joints increases coincidently with the moult. It is more probable that the latter takes place after the process of joint formation, and in this we may perhaps find the explanation of the just related facts respecting the loss of antennal hairs.

The number of ecdyses cannot be specified; I have found examples of all sizes in process of moulting, and can go no further than to fix it at not less than five. The adults and soldiers do not moult; and the latter are derived from soldier larvæ by an ecdysis, so that while the exuviæ are larval, the new instar is that of a fully-developed soldier.

As with other insects, the operation is accomplished by means of an anterior medio-dorsal fissure, through which are drawn out first the head and thorax, and lastly the abdomen (Pl. 16, fig. 15). In rare cases an example has been seen to be assisted in the operation by his comrades.

Two ecdyses merit special attention. The first is that undergone by the nymph, furnished with wings apparently small in size (really of full dimensions and elaborately folded up under the old ensheathing cuticle), and with genital appendices; from this it emerges with wings of full amplitude, and

without appendices should it be a female. The other important ecdysis is that in which the larva of a substitute royal form loses its genital appendices if a female, and this leads us to a detailed consideration of the latter organs.

The genital, often wrongly termed the anal appendices,[1] are homologous with those of the ninth abdominal sternite of Thysanura, and are attached in Termitidæ to what is apparently the eighth, but is really the ninth sternite, the first being fused with the metasternum. They possess hairs which do not differ from the ordinary hairs scattered over the body.

They are present in all sexually immature examples, but in the males only when mature. Further, the sternites differ in the sexes; in the female the true (not the apparent) seventh sternite is strongly developed and semicircular, and the true eighth and ninth are small and possess a median fissure. In the male the true seventh is rather small, as are the true eighth and ninth, in which the fissure is wanting. There is no penis.

I have but little to say about the internal organs. The tracheal system agrees with Fritz Müller's description,[2] and I have likewise observed the stigmata, tracheal trunks, anastomoses, &c. Further, this species exhibits the blind tracheal branches figured by Müller, which I take to be suppressed trunks or tracheal vesicles.

The alimentary canal presents the following features. In newly born larvæ the teeth of the proventriculus are colourless and quite soft,—that is, covered as yet with a delicate cuticle; and the Malpighian tubules are four in number. Four others appear at the epoch when the antennæ possess eleven distinct joints, of which the third and fourth are glabrous, and the former shows traces of division into two; these new tubules require a certain time in which to attain the size of the original four, and I have found them to be still

[1] [The genital appendices must not be confused with the abdominal appendices or cerci, referred to on p. 268.—W. F. N. B.]

[2] ['Jen. Zeitschr.,' ix, pp. 257, 259, pl. xiii.]

much the smaller when the number of antennal joints has reached twelve, with the fifth joint already pilose, or with the third and fourth alone bare. I may note here that the appearance of intestinal Protozoa (vide infra) coincides with this last stadium, though Joenia is confined to the large-headed larvæ, whereas Monocercomonas is common both to these and the small-headed forms.

The development of the four secondary Malpighian tubules proceeds in such a way that each is placed midway between a pair of the primary tubules; that is to say, the latter are equidistant from each other, and the secondary tubules are intercalated at equal distances between them, so as to produce a series of alternate large (primary) and small (secondary) tubules.

Their mode of development is shortly as follows: they spring from the proctodæum at its junction with the mid-gut, exactly at the same level of the primary series. I have been unable to detect any special layer of embryonic tissue destined to give origin to them, and they may therefore be regarded as a direct derivation from the proctodæal epithelium.

When the antennæ possess twelve joints, all pilose, the difference between the earlier and later Malpighian tubules has ceased to exist.

The salivary glands are highly developed in all castes and at every stage of growth. There is a single pair, as well as a large salivary reservoir, such as Müller has described (Pl. 19, fig. 7).[1] There is an unpaired external opening in connection with the labrum.

[The supra-œsophageal ganglia are situated as in Thysanura, with the olfactory lobes anterior, and the fungiform bodies posterior as in Termes lucifugus (see figs. 27—33*c, fung.*). The latter are relatively well developed when compared with those of Embiidæ (fig. 34) or Thysanura; there are two on either side, or four in all, not well separated from each other. As in other insects, they are characterised by

[1] ['Jen. Zeitschr.,' ix, pp. 256, 257, pl. xii, fig. 42.]

the possession of small cells, of which the nucleus stains more intensely than in the other nerve-cells.

Should a characteristic feature of these organs be sought, by way of contrast with those of less intelligent insects, it will be found in the abundance of these particular small nervous cells.]

The visceral nervous system is well developed, and resembles that of Blattidæ (fronto-labral commissures; frontal and stomato-gastric ganglia, &c.). The salivary glands are supplied (only?) by branches from the subœsophageal ganglion, coming off from those to the labium or lower lip.

The ventral ganglionic chain possesses six abdominal ganglia, and thus agrees with Lespès' description; the sixth is very large, and is in correspondence with the true seventh and eighth abdominal segments.

At the level of the fourth abdominal ganglion—that is, in the true fifth segment—there open numerous unicellular glands of unknown function. The retro-cerebral gland, which exists in Termes lucifugus,[1] is absent.

Certain features of the different castes and larval forms will now be described.

[Newly born examples are semi-transparent and almost pure white. If the mouth parts are detached the apex of the mandibles and the inner lobe of the maxillæ can just be seen with the microscope to be tinged with yellow, a feature which cannot be made out by examining intact specimens even with a good lens. After a few days these parts acquire a more or less pronounced yellow colour, owing to the thickening of the investing cuticle, and at this time a yellow line, caused by the approximated tips of the mandibles and maxillæ, may be distinguished at the front of the head even with the naked eye, though better with a lens.

This yellow line appears early in forms which develop a large head (soldier larvæ), and is delayed in those of which the head remains small. At the time of its appearance the animal

[1] [Vide Pl. 16, figs. 28—33, and description.]

is seen to adopt as food a material which is usually of the same dirty yellowish colour as that of more developed examples, and is apparent through the translucent abdomen, so that the general white colour of the body is blotched with yellow. The importance which attaches to this fact will be explained in the subsequent chapter.]

The youngest soldier larvæ are therefore distinguishable by the greater size of the head and the lesser constriction of its anterior portion, as well as by the yellow line in this region; moreover the thorax and the abdomen, which possesses the aforesaid yellowish blotching, appear to be somewhat wider.

The body of small soldiers (5 mm. in length) does not become fully yellow, with exception of the head, which is golden-yellow, and the mandibles, which are brown. Their head is subglobose, and at first sight these small soldiers greatly resemble those of Termes lucifugus, but are distinguishable by the indistinctly marked neck. The relative width of the head and pronotum varies in soldiers of different sizes, as is shown in the plate (Pl. 16, figs. 5, 16).

The body of medium-sized or large soldiers is golden-yellow, much deeper anteriorly, while the mandibles are coloured as in the small soldiers. The head is rectangular, and longer than broad, subquadrate. At the time of differentiation all the soldiers, large and small alike, are white, as I have stated.

True kings and queens (6·5 to 7 mm. in length) of recent development are black, except for the apical portions of the legs and antennæ, which are light yellow, and the anterior three fourths of the pronotum, which are golden yellow. With increase in bulk, at the first moment of the assumption of the definitive habit, the white intersegmental linear spaces become evident, and are most conspicuous when the royal forms have reached the maximum dimensions of which they are capable (Pl. 16, figs. 7, 11). I may note here that a length of 10 mm. for the king and of 14 mm. for the queen is the greatest that I have observed.

These white lines, which are not as yet evident in royal

forms as much as two years old (figs. 8 and 9), correspond with the interspaces between the first and second, and in succession to between the sixth and seventh abdominal somites. The second line is usually the widest, but is sometimes similar to the others. They occur alike in both sexes, but as the king increases in bulk less than the queen, they are naturally less marked in the former than in the latter sex at the same age and never ultimately reach the same degree of accentuation.

The substitute king and queen are distinguished not alone by the almost constant presence of pigment in the compound eyes, but also by their pale-yellow colour, which deepens with age to a golden tint.

In these royal forms alike the abdomen becomes enlarged, and I have found examples of both sexes almost equalling the largest true kings and queens in size (Pl. 16, figs. 12, 13). With the natural dilation of the abdomen, certain intersegmental spaces, namely, those which are indicated above for the true king and queen, appear as whitish lines.

I conclude by mentioning that I have looked in vain for any difference between the legs of the various forms. The tarsi are normally four-jointed; and the apex of the tibia possesses three spines, toothed on one side, and common to all the legs (Pl. 16, fig. 24). A plantula is present in the true imagos, but is wanting in all the other members of the colony, including the substitute kings and queens.

These observations probably hold good for all species of the genus Calotermes; I infer this from the many incomplete notes which are scattered in the pages of various writers.

4. Relative Numbers of the Castes.

A nest contains a single king and queen, neither of which can be normally wanting. They may be either true or substitute forms. At times one of the pair, either king or queen, is a perfect and the other a substitute form; and in such cases we have the strange phenomenon of courtship between a black and a yellow example.

The existence of but a single royal couple is an assured

fact, but it is not uncommon for two or more nests of Calotermes to co-exist without (at least for us) well-defined limits in the same stem, which therefore appears to contain more than a single royal pair. In connection with this condition are certain facts which prove the existence of the terrible jealousy which is so remarkably shown, e. g., between separate families of the hive-bee. But for the sake of convenience I shall defer them to a succeeding section on Habits.

When a colony is deprived either of king or queen, or of both, it furnishes a certain number of substitute royal forms, of which only one, if a single true form is missing, or two, that is, a pair, if both are absent, is called to the throne.

In every nest, forms of different ages are always to be found; and as a general rule small individuals are more, or not less, numerous than large.

Soldiers are relatively scarce, not more than from two to four being found in nests of from eight to fifteen inhabitants. In large colonies they exist in the proportion of one to very fifteen or twenty examples.

5. Seasonal Variations in the Colony.

It must be recollected, as a general rule, that the development of Calotermes is arrested during the winter months, that is, from the middle of November to the middle of April; and this condition explains the absence of individuals in process of moulting during that period.

In these months the nest contains eggs, sometimes a hundred or more, which are always in the gastrulation stage. Their development remains stationary during the greater part of May, to recommence towards the end of the month, so that newly hatched young are to be found from about the 10th of June till the end of July, a few eggs, from five to ten, hatching every day. In July it is evident that the number of young larvæ increases, so does that of the eggs diminish until their final disappearance. Towards the end of July it is difficult to find a nest which still contains eggs, proving that oviposition is suspended at this time. The same holds

good for the interval from November to the middle of May; while the opposite condition exists in the second half of May, in June, September, and October. Consequently oviposition remains suspended during winter and a large part of the summer. At the end of October many eggs are still to be found in the gastrula stage, and it follows from the preceding statements that they remain thus during the winter; but at the same month a certain number can be found in an advanced stage of development. From this, and from the fact that many new-born larvæ are to be found in that month, I can confidently state that the eggs laid in September (and perhaps in the early part of October) develop immediately without need of hybernation.[1]

At all seasons, except from about April to the middle of June, larvæ, with the features of being newly hatched, are to be found in the nests of Calotermes. The larvæ which are born in the second half of October make no progress in development until the following April.

Larvæ in stages of development which succeed those with the characters of recent hatching are to be found at all times of the year.

Nymphs are to be found in every nest during nearly all the year, being absent at most only in August and September.

The perfect insects develop from July to October, a few stragglers appearing in the spring. Their swarming is quite different from that observed in bees, and they leave the nest a few days after they become black. [As development is not simultaneous, they swarm in small groups of at most thirty examples, and occasionally singly or in pairs. A colony may therefore swarm, so to speak, ten or twelve times in all, from July to October.]

This fact explains the existence in many nests of a few winged examples still at the end of the swarming season, that is in October.

[1] I must admit that there is a certain gap in my observations in the summer months, when I am unable to reside at Catania owing to the excessive heat.

[As a rule a certain number of both sexes become mature at the same time, and the males invariably take flight two or three hours later than the females.] Further details on the subject of swarming will be found in the later section on Habits.

Soldiers and soldier larvæ are to be found the whole year round, but only small soldiers are present in nests under two years old.

6. Duration of Development, of Life, &c.

These matters are very difficult to ascertain, but the following facts are certain:

1. Owing to the interruption of development from November to April, individuals in the same stadium may be of different ages.

2. Eggs which pass the winter in the gastrula stage will give rise in the following summer at most to soldiers with 15-jointed antennæ, or to larvæ with similar antennæ, and with or without very short wing-rudiments. These larvæ become perfect insects and swarm in a later summer.

These conclusions are the result of minute examinations of numerous small or orphaned nests, &c., some of which I shall proceed to record.

By searching in the situations which have been described as the points of origin of new nests, from August to April, some two to twenty perfect insects, with the wings reduced to stumps, may easily be found; the majority are grouped in pairs, male and female, each of which may be accompanied by a few eggs. These pairs are recently formed, and, if originally numerous, are subsequently reduced to one or two (see the succeeding section on Habits).

A pair is established, say, in August, and remains to the end of the autumn with only fifteen or twenty eggs; twelve months later, at the end, that is, of the following autumn, it will be surrounded with fifteen, twenty, or at most thirty young of different ages, the most advanced being large soldiers with at most fifteen antennal joints, or larvæ with a similar number, all pilose, and with a very slight indication of wings.

I must regard certain nests which may be found at the end of October, as having arisen from pairs which had only begun to lay eggs in May of the year following the swarm-period. In these the number of inmates is less than in the nests previously referred to, and no larva possesses more than fourteen antennal joints, the third being glabrous, and the constrictions between the 3rd, 4th, and 5th respectively being ill-marked. The wing-rudiments of these larvæ are not yet discernible, and the soldiers of such nests do not possess more than twelve antennal joints, and are small.

The hypothesis that such nests may have originated from royal pairs disclosed only during the preceding summer, instead of the previous year, and consequently only three or four months old, is quite untenable; as is indicated by the fact that nests are never found to contain only newly hatched or little-grown larvæ at the end of autumn, as must of necessity be the case if young can be born in the year in which the nest is founded. In short, the fact remains that at the end of autumn certain nests are found to possess undeveloped eggs only, whereas others already contain small soldiers, and larvæ with fourteen antennal joints: nests intermediate between these two classes are entirely wanting, though they should be present if the above hypothesis were correct, inasmuch as the swarm-period lasts from the end of July till that of October.

In March, 1891, I observed an absence of nymphs in the examination of several nests orphaned two years previously (occasionally they were present in very small numbers). These nests contained ova and forms in all other stages. It therefore appears that destruction of the royal pair in spring results in the suppression of swarming during July and August of the second succeeding year, but in those months only, because examples in which the wings are only just indicated in March will have become imagines by September and October.

Nests orphaned between February and June sometimes contain no eggs, and usually no new-born larvæ in the following winter.

It is consequently evident that the development of substitute royal forms proceeds very slowly.

The data furnished by orphaned and young nests, and by many other observations which I have made, indicate that perfect and fully winged examples are not obtained before August from eggs laid in July of the preceding year. In short, Calotermes passes part of two years in the larval and nymph stages before taking flight. The soldier may complete its development in the same year in which it is hatched.

It is difficult to say anything about the duration of life. I must deny the existence of any particular season when the soldiers die off, as Lespès has claimed for Termes. The life of the king and queen may be estimated at four or five years at least.

7. Situation of the Different Forms in the Nest.

I have already mentioned that Calotermes does not possess a royal chamber. The king and queen, whether true or substitute, usually remain in close proximity in the heart of the nest, where the inmates are always most crowded. They readily change their situation. The eggs are mostly near them or a little way off, and are never heaped together.

Larvæ, nymphs, and winged forms, if present, are irregularly commingled; but larvæ newly hatched tend to cluster together. The soldiers also are irregularly scattered, but a few are often found in close attendance on the royal couple. The soldiers are generally the first to make their appearance when a nest is opened.

Substitute forms in process of development occur separately, or in groups of two to four in different parts of the nest.

It thus follows that the component members of a Calotermite colony have no special situations in the nest.

8. Certain Habits.

I propose to deal here only with those habits which could not appropriately be dealt with in Section 3.

Calotermites work, feed, and rest indifferently by day or night. When resting, they remain motionless without adopt-

ing any special attitude. They are fond of darkness, and when kept in a tube occupy the portions furthest from the light. They certainly work more actively in the dark, but are capable of doing so even when exposed to daylight.

Oviposition continues both by day and night.

Swarming takes place in the morning, usually from 9 to 12; and it must therefore be recognised that Calotermes no longer avoids the light when it has reached the perfect stage.

Before swarming the winged insects collect habitually in a spot which careful observation shows to be in the neighbourhood of an exit-hole, putting the nest into communication with the outer air.

Swarming takes place through this hole. The insects issue by ones or twos, so that the twenty or thirty examples ready to take flight emerge in perhaps a quarter of an hour.

Once outside the nest, they run upwards for a few metres if the locality admits of it, and then only do they take wing. In a room they evidently fly towards the light, and if a wind is blowing they follow its direction. Some soon become tired and settle on the trunks or branches of neighbouring trees; the majority become lost to sight, but many certainly end by alighting on trees. It is here that they group themselves into pairs, the males and females of which must frequently be derived from separate nests, for, as I have mentioned, the sexes swarm separately; this acts as a safeguard by which Calotermes habitually avoids in-breeding.

The winged forms have not been observed to pursue each other in the curious way which will be spoken of under Termes.

I may describe more precisely the manner in which the males and females come together when settled on a tree. The winged forms habitually search for a decayed spot, and when found they dig it out, after losing their wings, in order to bury themselves; it is in this act of excavation that the meeting and subsequent pairing take place.

The wings may be shed, merely by striking against an

obstacle, or by becoming damp and adhering to some spot, while the insect continues to move about.

But if not favoured by chance the Calotermite rids itself of its wings, as the following observation shows. Four perfect insects, which had recently left the nest, were captured by hand after flying about a room for some time, and were put under a piece of rotten wood. They had hardly settled down before they began to strip off their wings by resting their tips against some projecting corner of the wood and then moving backwards a little, so that the wings buckled towards the base, broke, and dropped off. When rid of them they began to gnaw the wood, at first along, and then across the grain; each worked by himself and at some distance from his fellows. Subsequently several chance encounters took place between them; they threatened to bite each other, and then ran off in different directions. They were of the same sex. If they had been of different sexes they would certainly sooner or later have copulated.

In the colony of Calotermes all members work for the common welfare. The soldiers serve for defence, but as a rule only when some important enemy has to be combated; at other times nymphs and possibly the older larvæ assume the task.

Cremastogaster scutellaris, Ol., which is abundant here, is one of the most formidable enemies of Calotermes, near which it makes its own nests. This ant enters the termitarium to massacre, whereas its own nest is never invaded by the Calotermite soldiers. If some examples of Cremastogaster are put into a tube containing a Calotermite nest, the following phenomena can readily be followed. The soldiers place themselves with gaping mandibles, waiting for any enemy that may come within reach. They then snap their jaws rapidly, shearing off antennæ and legs, tearing the abdomen, or even cutting the ants in two at the level of the abdominal petiole. The soldier's mandibles are seen to act like extremely sharp shears.

The ants themselves attack the Calotermites indifferently, but habitually avoid the heads of the soldiers, only daring occasionally to attempt to lop off their mandibles. As a rule they attack the soldiers from behind by biting the abdomen, and to protect it the soldiers creep under pieces of wood so as to leave the head alone free.

If a few Cremastogaster and a larger number of Calotermites are put into a tube, peace is usually concluded after about an hour's conflict, with a certain number of dead and wounded on both sides. The ants take up a position in one part of the nest and the Calotermites in another.

[Besides the ants, the soldiers of Termes are terrible enemies, but being small they are easily cut in two through the thorax by the Calotermite soldiers. The workers of Termes are much less dangerous enemies than the soldiers of that species. One, put into a tube-nest of Calotermes with soldiers, was at once placed hors de combat by a nymph, which cut off part of the buccal apparatus. Then sundry large larvæ and other nymphs hurried up, bit off its legs, and tore its abdomen until the viscera protruded. The soldiers took no part except towards the end of the struggle, when one gave it a bite. Similar observations have been made several times, and show, as we said before, that the soldiers purposely reserve themselves for more important foes.

Another Termes worker was put into a Calotermes nest containing no soldiers. The inmates took flight, probably terrified by the knowledge that they were unprotected by soldiers; and the Termes succeeded in throwing the nest into confusion, until after some lapse of time a nymph plucked up courage to bite its abdomen, and thus killed it.

A substitute queen of Termes lucifugus was introduced into another tube containing a Calotermite nest. A soldier promptly despatched her by decapitation, and then only did the nymphs intervene to tear the body. During the rest of the day the soldier never moved from the spot where he had killed the queen.]

Besides protecting the nest the soldiers fulfil other duties,

such as that of carrying the young and eggs on their mandibles. These organs are useless for gnawing wood, and their possessors therefore remain idle for hours together, while the rest of the colony is in full activity. Except for these tasks of defence from great dangers and wood-gnawing and consequently excavation of galleries, it is, so to speak, an absolute rule that all labour necessary for the community can be undertaken by any of its members.

Newly hatched larvæ can be seen carrying a fragment of wood heavier than themselves. All forms except the soldiers excavate galleries, provided that their mandibles are sufficiently strong, which naturally is not the case just after birth or after a moult. Both king and queen, whether true or substitute, gnaw up wood and transport excreta, eggs, or wood-meal.

Oviposition appears to be a very laborious process; in one case the egg was not extruded until an hour, and the succeeding egg until half an hour after appearance at the vulva. Once I saw a soldier assist the queen by raising and gently stroking her abdomen, but as a rule she lays without assistance.

Hatching is effected without need of any assistance from inmates of the colony. The chorion is tolerably thick, and the eggs can be kept in a watch-glass without drying up, and the process of hatching observed. Moulting also is accomplished as a rule without assistance.

If the eggs and young are exposed by opening a nest, it is striking to see how the other inhabitants disperse without paying them the least attention, in contrast to the behaviour of ants; and yet one must recognise that the colony is as deeply interested in their welfare as ants are in that of their own offspring, and that it scatters simply because it is panic-stricken. This may be proved by shaking a small nest made of loose pieces of wood in a glass tube or jar. For a moment all the inmates are thrown into disorder by terror, but they quickly recover themselves, become persuaded that it was merely an earthquake, so to speak, and devote themselves to the restoration of order by carrying the eggs back to their place at the bottom of the jar, and removing the young on the

mandibles of the soldiers, or in the mouth-parts of their other fellow-inmates.

It must be recognised that Calotermites are perfectly well aware of the presence or absence of the royal pair, and they start about providing fresh ones directly they are orphaned. The following observation is important in this connection. A nest was divided, say, into three smaller nests, in one of which the royal pair was retained; they were put into separate tubes, kept together and uncorked in the same waistcoat pocket. After three or four days larvæ of substitute royal forms were found in them, except in the one containing the royal pair. The colony in the tree from which the original nest was taken had not turned their attention to raising substitute forms, though they were 30 or 40 centimetres distant from any king or queen; whereas those in the tubes, though in close proximity to a royal pair, had at once begun to provide substitutes. It follows that the existence of the royal couple is certainly not perceived by means of any odour which they emit; and this affords us another marked contrast with what is observed in the case of bees.

The copulation of Termitidæ has been extensively discussed; some writers believe it to be accomplished in the open air, but the more general opinion is that the presence of the king in the nest shows that it takes place there, and is repeated from time to time. I regarded the latter supposition as possibly correct directly I found that the king is invariably present in the nest, and that his bulk increases, though to a less extent, concomitantly with that of the queen.

At last, on April 17th, 1891, about 11 a.m., I detected the king and queen in coitu in a glass jar containing a small Calotermes nest. The pair appeared to be about three years old, judging by their size. They stood end to end in a straight line with the tips of their abdomens applied to each other; their attitude was normal, with the dorsum uppermost, except for a slight upward flexure of the apex of the abdomen. After some half-minute they separated, perhaps owing to the ex-

posure to light. The contiguous parts of their abdomen exhibited a white substance which, when the king and queen became detached from one another, remained adhering under the hinder extremity of the queen.

It is therefore certain that connection takes place in the nest and is repeated at intervals; and all my observations satisfy me absolutely that it cannot be accomplished in the open air, and is practicable only after loss of the wings.

[I must regard certain relations which were observed to subsist between two substitute forms still far from maturity, because they were only about a fortnight old, as amatory in nature. One stood still while the other gradually approached, and when sufficiently near brought its antennæ into contact with those of its fellow; it then quickly retired for some distance, and returned later to repeat the pastime. This took place at least four times. On the fifth occasion the one which had been standing still, made movements as if to detain its companion; they then remained together, and very rapidly stroked various parts of each other's body, especially the apex of the abdomen. Their position during the reciprocal palpation of this part was almost that assumed during the act of coitus.]

Several writers have mentioned the convulsive movements characteristic of Termitidæ. These movements or quiverings are easily observed in Calotermes, and may be repeated periodically at very short intervals, almost at the frequency of the pulse-rate.

In the act of quivering the tarsi are held motionless, while the body is shaken forwards and backwards; there may be a simultaneous slight lateral or vertical oscillation. Sometimes an example may stop whilst running, in order to quiver one or more times.

Occasionally these convulsive movements are repeated a few times only, and then stop altogether; but at other times they recur after a few seconds or at most a few minutes' rest, and may thus be continued sometimes for hours with many similar intervals of rest.

In the intervals between successive convulsions the insect remains still or progresses for a short distance only. These movements are executed by all members of the colony except those newly hatched.

I have satisfied myself by careful observation of the phenomena exhibited in tube-nests that these convulsions serve as a cry to summon help or give alarm, or as a lament; in short, as a mode of intercommunication.

When the insects are suddenly annoyed or disturbed by any cause, such as a rough shake of the tube, its change from a vertical to a horizontal position, sudden illumination, or the prolonged effect of too bright a light, all the members of the colony begin to quiver, except those that are running briskly about in search of a better situation. Moribund examples sometimes perform these movements at intervals of a few minutes, in some cases for a couple of hours.

[If a few Termes lucifugus are put into a tube containing the usual little nest of Calotermites, some of the latter, evidently excited by the very rapid movements of the intruders, run off rapidly in the opposite direction, and stop at intervals to quiver with much more energy than usual. This phenomenon is exhibited alike by larvæ, nymphs, and soldiers, but the latter quickly turn back to face the supposed enemy. It seems evident in such a case that those which are first aware of the presence of the Termes quiver violently in order to alarm the population.]

[Sometimes the convulsions of an insect in the neighbourhood of the cork are quickly followed by the exit therefrom of others which have been burrowing inside it. Such cases appear to prove the utility of the action as a mode of signalling.]

Members of the same nest clearly recognise each other. [As a proof, a few examples are removed from the nest and returned after five or six hours. The population is not disturbed or alarmed, and does not scurry about at their re-entry. It is a possible objection that these specimens have immediately recognised the nest, and therefore create no disorder on their

return; to meet it a new nest was provided, from which certain individuals were excluded. They were introduced a few hours after the fresh nest was put in order and quiet, but they caused no disturbance although it was unfamiliar to them. As a control experiment, a few strange Calotermites were put into the same nest; the inhabitants took fright at once, and scattered in different directions. But after a little time all became quiet, and no fighting was actually observed. We may therefore conclude that examples taken from different nests readily fraternise; and this applies to the soldiers as well as to the larvæ and nymphs.]

[I should mention with respect to the soldiers that if too large a number is added to a nest, these supernumeraries, as they may be called, are found to be killed or eaten one by one during the next few days.]

[The following observation was made on one occasion. Half a dozen strangers, including a substitute royal example, were added to one of the usual nests in a tube. The royal specimen showed signs of hesitation and remained in the same spot, merely turning round and round, and straightening its legs as much as possible, as though to raise itself above the level of its neighbours. When an inhabitant of the nest approached and touched it, it drew back at once; the other did the same, so that they separated as rapidly as if they were stung. Some hours later the new-comer became quiet, and several inmates of the nest approached it to caress the antennæ, &c. I must mention that the nest was orphaned.]

[We have already stated that Calotermites furnish a certain number of substitute forms when deprived of the king and queen. Why then is only a single royal pair to be found? One day one of three substitute forms, which inhabited a small nest, was seen rapidly to pursue another with gaping jaws, with the evident intention of killing it, in which it was unsuccessful. Next day the nest contained only two such forms; very probably the one which was pursued the previous day had been killed.]

[Two true royal forms, a king and a queen, were introduced

into one of the usual nests, constructed the day before and containing only nymphs. One of the pair began at first to advance hesitatingly, while the other stood perfectly still; but shortly one after the other gradually moved forwards.

The nymphs then began to scatter in different directions in the endeavour to keep as far away as possible from the royal pair; these gradually retreated to the bottom of the tube, where they were left alone. But now and again a nymph approached with open jaws, and savagely bit one of the pair in the head or thorax, getting bitten with equal fury in return, and consequently retreating.

Next day the royal couple was still left unattended, but was no longer actually disturbed. Then a second similar pair was introduced; at once the nymphs all became greatly excited, attacked them and promptly reduced them both to helplessness by biting off their legs. The second pair was alive two days later, and the queen of the first pair was seen to attack the second king with open jaws; he retreated by dragging himself along the tube, being unable to run through the loss of all his legs. A day later he was dead, and the first queen was observed nibbling the stumps of his legs; on the following day the queen of the second pair was also found dead. Several repetitions of this experiment were made, and always gave similar results. Whenever two or three supernumerary royal pairs are put into a nest, a single pair is all that can be found at the end of a few days.]

I infer from all these facts that Calotermites exhibit those phenomena of jealousy and hostility which are so well known in bees; however, their manifestation is less rapid.

The observations just recorded, and many other facts omitted for the sake of brevity, lead us to the fundamental conclusion that the colony of Calotermes tolerates neither supernumerary royal examples nor supernumerary soldiers. Both one and the other are slaughtered. On the one hand, then, the colony can provide itself with royal forms or soldiers when they are required (vide infra); on the other hand, it rids

itself of them when they are over-abundant. These facts imply the possession by Termites of a faculty which may be termed a sense of proportion or numerical sense.

By way of conclusion, I must add that though I have had Calotermites under observation for several years, I may still have failed to detect a great part of their marvellous instincts. This is owing to two circumstances: 1, they are often sluggish; 2, when a nest is opened the population is thrown into such a state of astonishment that it usually does nothing but run away and give signals of alarm. And almost all the observations here recorded are due to the method of employing tube-nests.

The Colony of Termes lucifugus.

1. Situation and Nest.

Several writers, particularly Lespès, have published observations on this subject; but I shall summarise merely my own investigations.

Here in Sicily Termes lucifugus usually inhabits plants, rarely furniture or the wooden beams of buildings. It is most common in plants of which the stem or tap-root measures at least three quarters of a centimetre in diameter; but when it has once entered a stem or large branch it will pass on into the very smallest twigs and roots. It mines irregular galleries, and often avails itself of old beetle-burrows (Bostrychus, &c.); Calotermes does the same thing. Like that species, Termes leaves the outer layers untouched, so that a trunk may be completely mined out and yet appear sound, while the hand can easily be thrust into it by breaking through the thin intact superficial layer.

Owing to the extreme tenuity of this layer in the smallest roots invaded, the galleries may appear at first sight to be tunnelled directly in the ground; but I have never been able definitely to establish the existence of such a mode of construction.

I have never found Termes in the orange, lemon, or vine; but, unlike Calotermes, it is very common in cactus. It continues to live and flourish in perfectly dead and dry wood, even when employed in the construction of roofs, doors, furniture, casks, &c.

It is characteristic that whereas Calotermes confines itself to the original host plant, Termes successively attacks fresh plants or timber, and may thus pass from the furniture of a house to a tree, or the reverse, or from one piece of furniture to another. The following facts are related to this peculiarity:

A few workers of Termes, which are probably explorers, are sometimes found to make a spontaneous appearance in the open air and in broad daylight.

On other occasions Termites travel by availing themselves of natural cracks, e. g. in lava, or by hollowing out small dry rootlets underground, or in reeds by means of the tubular lumen. Frequently they have recourse to galleries, which are quite distinct from the burrows made in wood, because they are fabricated or built up, so to say, by the insects themselves. They are therefore not merely miners, but also builders. These galleries are of two kinds, tubular or D-shaped in section. Galleries are usually constructed in tubular form in the absence of any suitable base on which to build them; if such be present the gutter-shaped gallery (semicircular in section) is resorted to, but even in this case that part of the base which is enclosed between the walls of the tunnel is incompletely cemented over. Galleries of the latter kind are made by preference in the angle of junction of two walls (Pl. 17, fig. 40).

Gutter-shaped galleries may reach the considerable length of eight or more metres. In the choir of the principal church of Pedara I have seen such a tunnel leading from the stalls to a crack in the wall adjoining the wooden ceiling, in which the crack disappeared. The insects travelled between the choir and the ceiling by means of the tunnel and then of the crack, which they made use of apparently without modification. In such cases it is sometimes difficult to distinguish the track of the insects right up to the point where the gallery leaves off.

Similar galleries also occur in the spacious ceiling of the Benedictine church at Catania.

In the building of the Botanical Garden at Catania the Termites have invaded the benches of the school, the book-cases and window-frames, &c. Here I found two gutter-shaped tunnels over 40 cm. in length on the wall of a room; they began from the timber invaded by the insects, and ran along the surface of the wall, to finish at a point where no fissure was discoverable.

The direction of the gutter-shaped galleries may vary as required; they are usually vertical or oblique, less often horizontal, and they may branch in various ways. The tubular galleries are mostly short, rarely exceeding 5 cm., and are narrower than an ordinary pencil. They serve to connect two gutter-shaped galleries or two portions of a nest; and a gutter-shaped gallery may become tubular for part of its course.

On one occasion I found a much flattened tubular gallery about 15 mm. in width, 4 mm. in depth, and 5 cm. in length, and somewhat irregular. This fragile structure was suspended from the ceiling, and contained a certain number of Termites; there were some apertures at its free extremity (Pl. 17, fig. 38). At other times I have found much shorter flattened galleries hanging from the ceiling (Pl. 17, fig. 39; Pl. 18, fig. 15). The purpose of these structures escapes me, but, recollecting the excrescences built on plants by certain tropical Termites, I suspect them to be a rude attempt at a nest. A similar explanation may perhaps be advanced for the galleries found at the Botanical Garden of Catania, which terminated in a free extremity.

Both forms of gallery usually have a diameter from 2 to 6 mm. Their lumen varies at different points, and is generally large enough to allow several insects to pass at once; the internal surface is tolerably smooth, while the outer is irregular and rugged. Their colour is variable, but is usually of a chalky-grey tint. They are composed of fæcal and disgorged matter, and of triturated wood. When connected with a plaster cor-

nice they contain distinct scattered white specks, which are fragments of plaster.

These Termite galleries are invariably very light, porous, and friable. When the Termites meet with large empty spaces while in process of enlarging their nest, they may fill them up by building a complicated labyrinth, as many ants are known to do (Pl. 18, figs. 14, 16); and they readily adapt such projecting pieces of wood as the space may contain to what they are building by covering them over with the materials of construction, or cementing them suitably together.

Excellent specimens of both classes of gallery can be obtained by putting Termites into a glass jar half full of broken-up cactus-phylloclades, and closed with a cork or merely with a sheet of paper (Pl. 18, fig. 17).

If many such nests are formed, one or more can generally be kept alive for six, eight, or more months. I have published elsewhere an account of one of these nests, which I repeat textually.

"For eight months I have kept a colony of Termes lucifugus without king or queen in a jar half full of crushed-up phylloclades of Opuntia, and closed with a sheet of paper tied over the mouth instead of with a bung. The jar holds three litres, and its mouth is wide and polished.

"At the beginning of April the Termites were seen to have settled in the bottom layer only of the rubbish, and the remainder, some 7 cm. in thickness, was quite uninhabited. It was not till the 20th of May that a few specimens appeared in it. Some days later a semicircular gutter-shaped tunnel was found adhering to the walls of the empty part of the jar (the nest material occupying barely a half). This tunnel put the rubbish into communication with the paper cover, which presented a small aperture large enough to admit the body of a Termite at the extremity of the tunnel.

"All kinds of forms in the colony (larvæ, nymphs, soldiers, workers, and winged adults) went backwards and forwards by this gallery, which in its greater part would only allow room for a single individual at a time, but which widened here and

there so that two could pass simultaneously. This primary tunnel, as it may be called, was the only one constructed during five days, but it was made to bifurcate by the addition of a lateral branch. This came off at an acute angle from near the middle of the primary gallery, and ran upwards to terminate on the margin of the vessel, where the polished surface began. During the next few days the uninhabited part of the rubbish was tunnelled with numerous burrows, opening on its upper surface by several small holes, some of which were continued upwards by tubular chimney-like galleries of different heights (the largest measured 5 cm.), vertical or oblique in direction, and varying in width, usually just capable of being traversed by a single Termite. The free ends of these chimneys were sometimes closed, sometimes open, and in that case an inmate of the colony would not infrequently peep out as from a watch-tower (Pl. 18, fig. 13).

"Swarming took place on June 1st. On the following days the Termites did very little work, to all appearance. They lengthened a chimney and built another gallery like the first, but not connected with it and not reaching the lip of the vessel; and lastly, they made an incomplete extension of the primary tunnel by carrying it along the junction of the lip and the paper. The latter exhibited two fresh holes at this point.

"One day I destroyed the newly formed section of the primary gallery by taking off the paper, which I purposely put back so that it did not accurately cover the margin of the vessel, but left a gap; next day the primary gallery was continued horizontally outwards for about 1 cm. from the margin of the vessel; this new portion did not run on the surface of the glass, and, like the chimneys, was tubular instead of being semicircular (Pl. 18, fig. 17). A day later it was dismantled and destroyed by the Termites; this did not surprise me, as I had already observed them make and unmake portions of galleries.

"On June 20th the tops of the chimneys and openings were closed up, the galleries were unoccupied, and the whole of the colony had once more retired to the bottom of the vessel."

This colony was unfortunately killed at the end of June by over-dryness.

The structures built before swarming were certainly made chiefly for the purpose of facilitating that procedure. But similar erections, with the exception of the chimneys, can be obtained at a time remote from the swarm-period, or after it has elapsed, as in the case just described, where the Termites evidently found the vessel unsuitable, and attempted to abandon it, but were unsuccessful, and therefore all died.

I state that they endeavoured to quit the jar because on other occasions I have observed a general migration from a vessel which had been inhabited some time, the contents of which were found on examination to be unsuited to their welfare (too damp, mouldy, over-dry, &c.).

Termes *does not line the galleries hollowed out of wood* with excrement. The wood-meal produced by burrowing varies in colour with the material from which it is derived. Burrows are very easily made in certain cactus-phylloclades which keep their white colour after death, but become very soft; the inner surface of these burrows and the dust removed are both white.

Termites customarily select the softer parts of the wood, but when these are all destroyed they attack the hard parts, and thus form spacious chambers, openings, &c.

Temperature and humidity are as important for Termes as for Calotermes; and as far as is known at present the geographical distribution of these forms coincides.[1] But it must be remembered that the former can flourish at a somewhat lower mean temperature than the latter, so at least I imagine, for the following reasons:

Oviposition commences as early as the beginning of May. In October and November forms in intermediate stages between the nymph and the larva with the earliest indication of wings

[1] [Termes, however, extends farther north, occurring in France at Toulouse, Bordeaux, Rochefort, and La Rochelle, and in Italy in Tuscany and Venetia, the present writer having lately found a winged example at Venice.—W. F. H. B.]

are very scarce; they begin to appear in December, and become abundant in January and February. The nymphs accomplish the imaginal transformation by April or May. But the fact that examples with the characteristics of those recently born are to be met with in spring, though the nest may have contained no eggs since the month of September, shows that the development of the earliest stages is arrested during the winter, as in Calotermes. Termes, it must be noted, requires a less degree of moisture than Calotermes, and can therefore live with comfort in dry and seasoned timber, and in desiccated portions of trees, &c.

During the warmer months they bury themselves deeper and deeper in dead roots, so that their nests appear to be depleted, and it becomes difficult to procure complementary royal forms, eggs, new-born larvæ, &c., without digging to a great depth.

Termes and Calotermes often share the same tree, but the former habitually confines itself to the dead and drier, the latter to the moister parts. But it will readily be understood that there is no sharp demarcation between these two regions, and therefore none between the two colonies.

2. Number of Individuals in the Colony.

It is practically impossible to make any accurate estimate of the limits of a nest of Termes, as will be seen later. However, a single tree, which certainly does not harbour more than one nest, will contain at times as much as a litre of Termites. As a rule, the offspring of one nest extends to several trees, and the population of a single colony may therefore be reckoned as upwards of two litres—that is to say, very many thousand individuals.

3. The Different Castes (Plate 17).

The society of Termes lucifugus differs widely from that of Calotermes, or of such other Termitidæ as have hitherto been adequately studied.

Its characteristic feature is the invariable absence of a true

royal pair,—that is, a pair derived from winged imagos, which have lost their wings (except the stumps). This statement of mine will appear bold, but I have examined thousands of nests during a period of about seven years, and am in a position to make it without the least fear of contradiction. Small colonies, founded by a true royal pair, are to be obtained only by artificially enclosing winged Termes in glass jars partly filled with wood. Nothing of the kind is ever found in nature. On one single occasion I lighted on a true royal pair, though without eggs, in January,—that is, about six months after swarming.

For the present we may leave out of sight these artificial nests in glass jars to consider those found under natural conditions.

The principal differences between the Termes colony and that of Calotermes are as follows:

1. Termes possesses the caste of workers, which is wanting in Calotermes.

2. On the other hand, Termes has no true royal pair, but its place is supplied by a large number of sexually mature individuals, which I term complementary royal forms (Pl. 17, figs. 16, 17, 21). These complementary forms have the characters of larvæ just about to become nymphs—that is, with the wing-rudiments relatively shorter than in the nymph. Their length differs a little, however, in different examples, and occasionally they are entirely wanting.

3. Orphaned nests—that is, nests from which the complementary forms have been abstracted—contain numerous substitute royal forms. These may resemble the complementary forms, but their wings are frequently entirely wanting (Pl. 17, fig. 15), or else developed as in the nymph (id., fig. 23). Sometimes they have the characters of an imago which has become brown in a few places only, and has the wings mutilated (id., fig. 24).

The ordinary nest of Termes may evidently be compared with the orphaned nest of Calotermes, with this difference, that the former is much richer in royal examples, which

usually possess some trace of the wings, whereas these are entirely absent in most of the substitute forms of Calotermes.

The orphaned nest of Termes has a still closer resemblance to that of Calotermes, for the royal forms, as I have said, are frequently destitute of wing-rudiments.

In short, in the nest of Termes, as in the orphaned nest of Calotermes, individuals of which the wings have never been fully developed are invariably raised to the throne.

There is a further important distinction: in the Calotermes nest the king is always to be found beside the queen, whereas in numbers of Termes nests examined I have only twice found a single king associated with troops of queens. These kings were observed in the hot season,—that is, at the time when substitute queens are most difficult to find, because then the insects habitually bury themselves deep in the ground. I cannot doubt that I might have found many others if I had been able to continue my investigations in August and September.

The complementary or substitute king is certainly present in the nest about the time when the queens of either kind reach maturity, and he disappears after pairing. The colony must therefore rear fresh kings every year, which become mature in August and September, fertilise the queens, and die. By way of confirming this inference, I may say, in addition to the facts just related, that recently orphaned nests contain as many examples in process of becoming substitute kings as those about to become substitute queens. Complementary kings in process of development can be found from the middle of March onwards, but are always very rare in non-orphaned nests, while developing complementary queens are entirely wanting.

Finally, I may add that all possibility of parthenogenesis is excluded, as will be seen farther on, by the constant presence of abundant spermatozoa in the spermathecæ of the substitute queens.

A nest of Termes contains[1]—

I. Very young larvæ, the head of which is alike in those of equal length (Pl. 17, fig. 1).

They include forms from the smallest (scarcely 1 mm. long, with antennæ of eleven joints, the third bare, the rest pilose) (Pl. 17, fig. 1) to those a little over 2 mm. in length (with antennæ of twelve joints, the third bare, the rest pilose, sometimes with the fourth bare in one antenna only). Larvæ between these two groups are intermediate in length, and have either eleven pilose antennal joints or twelve, the third and fourth bare and the rest pilose. There are four Malpighian tubules in the smaller larvæ (Pl. 18, fig. 11), eight (four large and four small) in the larger (id., fig. 12). I may add at once that the smallest larvæ possess no parasitic Protozoa.

II. Examples 2·25 to 3·75 mm. long, with twelve entirely hairy, or thirteen antennal joints; some with large (Pl. 17, fig. 2), others with small heads (id., fig. 3).

Those with large heads may be regarded as young workers, and may become either adult workers or soldiers.

The smallest members of this group still possess four small [secondary] Malpighian tubules, and may be free from Protozoa (always from Trichonympha).

III. Examples with fourteen antennal joints, 3·75 to 4 mm. in length, with or without very short wing-rudiments.

They fall into the following category:

A. Forms without a trace of wings, with the head relatively large, the abdomen stout and rather short, and the colour of the body less conspicuously white (Pl. 17, figs. 5, 78). These are more or less immature workers, capable of becoming adults, or of transforming into soldiers. They are derived from either the large- or small-headed forms of the preceding stage (II).

[1] As before, I must assume a knowledge in this section of certain experiments which will be described later.

B. Soldiers with all antennal joints pilose. Derived from large-headed forms of the preceding stage (II).

C. Examples without trace of wings and with a relatively small head (Pl. 17, fig. 4). Derived from small-headed forms of the preceding stage (II).

D. Examples with very short wing-buds (Pl. 17, fig. 6). Also derived from small-headed forms of the preceding stage (II).

IV. Individuals 4 to 6 mm. or more in length, with fifteen or sixteen antennal joints. Some possess very short or partly developed wing-buds, and belong to groups C and D of Stage III (Pl. 17, fig. 9). Others have no trace of wings, and these may be of three kinds: A^2, more or less youthful workers; B^2, soldiers; C^2, larvæ of royal forms, complemental or substitutional, without sign of wings, and with the head small. A^2 are derived from forms A or C of Stage III; B^2 from forms A, possibly also from forms B, C, and D of Stage III; C^2, lastly, from form C of that stage.

V. Individuals with seventeen or eighteen antennal joints, incapable of flight, and infertile, or at least far from maturity.

These may be of five kinds: A^3, soldiers (with not more than seventeen antennal joints, all pilose) (Pl. 17, fig. 14); B^3, adult workers (circa 5 mm. in length) (id., fig. 13); C^3, "nymphs of the first form"[1] (7—8 mm. long), with long wing-pads, the genital organs little developed (id., fig. 10); D^3, "nymphs of the second form"[2] (4—8 mm. long, with more or less short wing-pads, the genital organs well developed) (id., figs. 19, 20, 22); E^3, larvæ of complementary or substitute royal forms, without trace of wings (7—9 mm. in length). As will be seen later, the forms D^3 are also larvæ of royal substitutes. Form A^3 may originate from A^2 of Stage IV, and perhaps from B^2 as well; B^3 is derived from form

1 [Lespès, 'Ann. Sci. Nat.' (4), v, pp. 248—251, pl. v, fig. 6.]

2 [Id., pp. 251—254, pl. v, fig. 7.]

A² of Stage IV; C³ and D³ from the forms with wing-buds of Stage IV; and lastly, E³ always from form C² of Stage IV.

To this fifth group belong further certain individuals which I regarded as abnormalities before I was acquainted with the facts I have recorded about the soldiers of Calotermes.

They are nymph-soldiers, or nymphs with the buccal apparatus of soldiers. They probably lose their wings and become simple soldiers, as do those of Calotermes.[1]

VI. Perfect insects—that is, with fully developed wings and capable of flight (Pl. 17, fig. 11). The number of antennal joints remains, as in the nymphs, at seventeen or eighteen, but they are always entirely pilose. These specimens are distinguished by a general piceous colour, save for the mouth parts, tarsi, and apices of the tibiæ, which are testaceous. They originate from the nymphs of the first form.

VII. Complementary (Pl. 17, figs. 16—18, 21) or substitute (id., figs. 15, 22, 25) royal forms, sexually mature, or nearly so, but in the guise of the larva or nymph, or else resembling an imago, partly infuscate and with the wings torn.

The latter spring from immature, not fully darkened perfect insects; the others, in the larva or nymph form, arise from the royal larvæ E³ of group V, or from nymphs of the second form, or finally from nymphs of the first form (fig. 23). The royal forms derived from nymphs of the first form or from not fully darkened perfect insects are all substitute, never complemental forms.

The wing-rudiments may be wanting, or more or less short. The body may be of the whitish yellow of old paper, or may be more or less extensively blotched with brown. The abdomen is much inflated, so that these forms are generally recognisable at a glance.

They exhibit a further characteristic in the possession of

[1] It now seems to me probable that they should be compared with the egg-hatching workers of the honey-bee.—G. B. Grassi, October, 1896.

longer abdominal hairs than those of the nymphs and perfect insects; these hairs are generally transverse in direction, whereas they point obliquely backwards in the nymphs and imagos.

The number of antennal joints may increase in the adult workers, larvæ of complementary or substitute forms, and perhaps in the soldiers, to the maximum figure stated above.

The general law laid down for the castes of Calotermes is equally applicable to Termes, with the introduction of a slight modification, due solely to the existence of the workers, which are wanting in Calotermes.

It will stand thus:—The regular development of Termes up to the perfect insect may undergo a deviation at various periods of life, which leads to the formation of workers, of complementary or substitute royal forms, or of soldiers; the last passing through the stadium of the young worker. The deviation in question may take place at various periods.

As the anatomical structure of Termes is in general agreement with that of Calotermes, I shall restrict myself to a few very brief remarks thereon.

Turning to the sense-organs, it is noticeable that the soldiers of this genus do not possess compound eyes, nor do the larvæ which become sexually mature, until the wing-rudiments begin to appear. Consequently the complementary and substitute royal forms, which have no trace of wings, are equally destitute of compound eyes. But these are present and pigmented in all the other complementary and substitute forms. The pigment is also acquired by the nymph of the first form when just about to change to the perfect insect.

In the nymph of the second form there is a distinct structure in the neighbourhood of each compound eye, which I interpret as a rudimentary pigmentless ocellus. This may also be easily seen in nymphs ready for the final change and in the perfect insect; but I have been unable definitely to find it in substitute forms (I have not looked for it in sections).

The well-known law of Fritz Müller as to the increase in the number of antennal joints is certainly inaccurate for Termes lucifugus.

The 11-jointed antenna acquires its 12th joint by subequal division of the 3rd, so that it cannot be said whether the resulting 3rd or 4th is the younger. When the number of joints exceeds twelve it is an indisputable rule that the third is the youngest if the number is odd, and the fourth if the number is equal. And when the number of joints is odd no fresh joint develops until its predecessor has become pilose; for I have never found an example with an odd number of joints which were all pilose, while it is easy to find examples with an equal number of joints which are or are not all pilose (Pl. 17, figs. 28—37).

I shall now describe the substitute and complementary royal forms somewhat fully.

They rarely exceed 11 mm. in length, and those without trace of wings probably never attain a length of more than 6 or 7 mm. The only two kings I have found measured about 7 mm. in length. The shape both of the head and thorax in the examples possessing wing-rudiments is exactly similar to that of the nymph, and therefore of the perfect insect. On the other hand, those which have no sign of wings find their parallel in the small-headed larvæ; their pronotum has a characteristic shape, which will be better understood from the figure than from a laborious description, and which distinguishes them from the workers without a shadow of uncertainty (Pl. 17, figs. 26, 27).

The colour of the body, as before mentioned, is generally of the pale yellow tone of old paper, sometimes with an aureous tinge. The head is dull aureous-yellow, with brown compound eyes, which are wanting, as I have said, in the completely wingless forms. Many old examples exhibit large areas which appear brown or sepia-coloured to the naked eye, but are seen under the microscope to be yellow sprinkled with minute black spots. These areas are as follows:

1. The thoracic and abdominal terga (fig. 17). The latter, however, exhibit an immaculate longitudinal median vitta and a similar rounded spot on either side. The vitta may or may not be evident on the metathoracic, and is wanting on the mesothoracic tergite; it is present on the pronotum, where it forms a cruciform mark with a similar transverse vitta towards the apex. As a rule the side margins of the pronotum are also immaculate.

2. The lateral limb of the abdominal sternites; but a few black spots may also be seen to exist over the median portion.

3. The thoracic pleuræ (side-pieces).

4. The basal portion of the legs.

It is important to notice that completely yellow examples may at times have the wing-rudiments more developed than in those with brown markings, although the greater abdominal development, or their known history, may show the latter to be the older.

The wing-pads are dirty white and exhibit abundant tracheæ, arranged as in the fully formed wing.

Hairs are distributed everywhere except on the intersegmental spaces. As I have already said, those on the abdomen are longer and transversely directed (figs. 17 and 18), and thus distinguish these forms from those in which the wings are fully developed (fig. 12). The genital appendices are always absent in the female.

T h e a b d o m i n a l h a i r s a n d b l a c k m a c u l a t i o n f u r n i s h c h a r a c t e r i s t i c p o i n t s o f d i f f e r e n c e f r o m t h e f u l l y w i n g e d f o r m s. The latter are found to become black by uniform darkening,—that is, without first presenting the black spots peculiar to the complementary or substitute examples.

The number of antennal joints in this latter group of royal forms is variable, and may differ on each side of the head; it may be 14, 15, 16, or 17; but the last number is exceptional. In no case are the antennæ intact, as the examination of the last joint as well as the third and fourth shows (Pl. 17, fig. 29). I have found queens without indication of wings and with sixteen-jointed antennæ, which were obviously truncated at the

apex; and the condition of the third and fourth joints being pilose, led me to infer that eighteen would have been present if they were intact. But this is never the case in these forms.

There remain for description those substitute forms which are derived from perfect insects which have not become black, and have the wings torn off (Pl. 17, fig. 24). They measure about 6 mm. in length, and possess the customary long outstanding hairs. The dark compound eyes are conspicuous, and the ocelli can also be made out. The antennæ are curtailed as usual, and the wings are rarely torn off exactly along the hind margin of the squama, but so as to leave an additional portion of varying, usually small size, the laceration following a very irregular course, as if the wing had been gnawed off.

The body is generally of a yellow colour, and is not spotted with black, but the margin of the pronotum, especially the posterior, and the hind margins of the meso- and meta-notum are of a uniform brown, even when seen through the microscope.

Occasionally the head and the entire meso- and meta-notum are brown; frequently, also, the thoracic pleuræ and the outer face of the basal portion of the legs. In some examples the apex of the abdomen is brownish. In some the wings are of a uniform dirty white, but in many others the squama, the costal margin, and perhaps part of the torn edge are brown.

The genital appendices are present in the male, but are wanting in the female, as in other complementary and substitute queens.

The stages of growth of substitute or complemental forms with longer or shorter wing-buds are important, and require notice. They are to be found by selection of the examples with seventeen or eighteen antennal joints and rudiments of the wings. According to Lespès' classical researches, these examples are of two kinds, with the wing outgrowths respectively strongly and feebly developed. The former (fig. 10) are his "nymphs of the first form;" the latter (figs. 19 and 20),

his "nymphs of the second form," are further characterised by the bulkier and more ovoid abdomen. The eyes of the latter group begin to become pigmented and prominent, and their ocelli are visible. Their antennæ are intact, and the hairs resemble those of the nymphs of the first form.

These nymphs of the second form become complementary royal forms by a moult in which they acquire the characteristic direction of the abdominal hairs and, if of female sex, lose the female genital appendices.

They exhibit a marked development of the genital organs which will be subsequently described.

In the examples, previously mentioned, of which the head begins to enlarge, much the same development of the mandibles and maxillæ takes place as in Calotermes flavicollis.

With respect to the general colour of the inmates of the colony, I should add that the workers are normally dirty white or yellowish, and the soldiers more distinctly yellow; freshly moulted or very small specimens, and most undifferentiated forms, or those destined for sexual maturity, are pure white.

The legs are alike in all the forms; the anterior tibiæ possess three, the others two apical spines.

Adult and fully winged examples exhibit the well-known sexual differences of the seventh, eighth, and ninth abdominal sternites, viz.—1. The seventh (the apparent sixth) is strongly developed and semicircular (with the rounded edge posterior in the female), very short in the male. 2. The eighth is reduced to two lateral lobes in the female, and is small and entire in the male. 3. The ninth nearly resembles the eighth. A similar disposition is found in the mature substitute and complementary forms. As in Calotermes, the ecdyses are rather numerous in Termes lucifugus, and do not bear the supposed relation to the increase in the number of antennal joints.

4. Relative Numbers of the Castes.

It is impossible to indicate the relative numbers of the different forms with any degree of certainty, owing to the excessive difficulty of fixing the limits of a colony. But, as before, the soldiers of Termes are far less abundant than the other forms. The workers occur in enormous numbers; the young and larvæ are also very numerous, the "nymphs of the first form" relatively much less so.

Examples in process of development into royal forms are common only in trees which, though densely populated, contain no or very few royal forms. Nevertheless a certain number of male "nymphs of the second form" can easily be found from March to June, especially in trees containing complementary or substitute queens.

Complementary forms occur in 6 or 8 per cent. only of trees invaded by Termes, but in these there may be upwards of a thousand, though the number usually oscillates between fifty and two hundred.

Substitute royal forms, varying in number from about ten to two hundred, are confined to those nests which have been partially or completely orphaned, either by destruction of the complementary kings and queens, or by cutting down a tree and removing it a kilometre or so away from its original situation.

In the nests which I have mentioned as having been obtained in glass jars, a single true royal pair was found.

5. Seasonal Variations in the Colony.

The colony differs very much at different times of the year. Eggs are present in May, June, and July, and, in all probability, in August and September as well.

The youngest larvæ are never present in April and May.

Nymphs of the first form are not met with in June and July. Forms with tolerably well-marked wing-buds, and with fourteen to sixteen antennal joints, are absent or very scarce in October and November; they increase in number in December, to become abundant by January or February.

Winged imagos occur from the beginning of April to the middle of June (a few stragglers being exceptionally found as late as September).

The remaining forms are present, as a rule, all the year round, except the kings, or incipient royal forms of either sex.

The latter have already been repeatedly referred to, and must receive further notice in the following chapter.

Lastly, I must not omit to mention that nymphs of the first form are absent in some years from certain nests, which have probably been orphaned at a previous period.

6. Duration of Development, Life, &c.

The eggs hatch fifteen or twenty days after they are laid.

Many observations lead me to conclude that the very young larvæ found in the winter do not develop farther than the nymph of the first form in the following summer, and therefore must certainly live through a second winter before acquiring wings; e.g. larvæ born in October, 1889, will not have the wings fully developed until April, 1891.

Thus, too, the complete or almost complete absence in October and November of examples with 14—16-jointed antennæ and distinct wing-buds compels me to believe that those hatched in May have become nymphs already, or else that they do not yet possess fourteen antennal joints. The latter hypothesis is correct; for if the former were, a much larger number of nymphs ought to be found in particular nests than is actually the case.

A small colony obtained in a glass jar was furnished with a number of fully winged individuals in the early part of May; on the 20th of December it contained, beside the other inhabitants, five workers with 12—14-jointed antennæ.

Several orphaned nests were placed in large glass jars in January; next October they still contained small specimens with 13—14-jointed antennæ, while no substitute forms had developed.

These further facts agree sufficiently with the hypothesis which I regard as correct.

In conclusion, a lapse of eighteen to twenty months may be estimated to take place between the times of hatching and of reaching the perfect state. The workers and soldiers probably require a much shorter time, and both can apparently be developed by the autumn from eggs laid in May of the same year.

The duration of life of single specimens cannot easily be estimated. The soldiers and workers certainly do not die off about the middle of June, as Lespès pretends. The king, whether complementary or substitute, does not live more than a couple of months after reaching sexual maturity, whereas the corresponding queens will live for several years.

7. Situation of Different Forms in the Nest.

The fertile or nearly fertile royal forms usually live in a very remote part of the nest, often collected together in a deep root or in the heart of a large trunk.

The only two mature kings I have found accompanied the queens; the latter may be surrounded with numerous new-born larvæ and clumps of 30 or 40 to 100 eggs.

Eggs and larvæ can be carried long distances, as is shown by the occasional presence of numerous young larvæ and sometimes of eggs as well in trees destitute of queens.

The larvæ, nymphs, winged forms (if present), soldiers, and workers all occur mingled together, both in the midst of the queens and elsewhere. Recently invaded situations contain, as a rule, chiefly workers and soldiers; and isolated workers, which one is tempted to look on as explorers or pioneers, may sometimes be found under stones, or in reeds, &c. Certain parts of the nest often contain principally workers and soldiers; others larvæ with wing-rudiments and nymphs.

[I would add further that when a nest is opened certain parts will contain nothing but soldiers in the neighbourhood of the egg-clumps. It is a mistake to regard this as a normal state of things; the disturbance and noise of opening the nest have put all the other inhabitants to flight, while the valiant soldiers alone remain to protect the eggs.]

VIII. Certain Habits.

The swarming will be first described.

A swarm was observed on May 14th, 1891. A host of Termites issued in groups of two to five from a single crack in a tree-trunk, rose on the wing for about three metres, and then followed the direction of the wind. Many fell on the neighbouring plants, and others were seized by ants as they emerged. The swarm began at 10 a.m., and lasted for more than two hours.

This incomplete observation was made by the laboratory servant, who chanced to see a similar occurrence on May 24th, 1891. In the second case the winged forms were seen to issue from several holes, at which a few soldiers and workers also appeared. The imagos were all destroyed, at first by two lizards, which remained on watch near the nest and devoured them directly they appeared. When the lizards were driven off the insects were seen to come out in groups of six or eight, run a certain distance, spread their wings, and then take flight. At first they rose a certain height, and then followed the direction of the wind (a light scirocco). A few struck against branches and fell to earth, but they quickly got up again. This swarm lasted from about 9.30 to 11 a.m. When it was over the nest was opened, and found to contain many imagos ready for swarming about half a metre from the exit-holes. These were all females, as were those (twenty-six) collected during the swarm.

Sinilar swarms were observed on various other occasions. One of special interest took place in the laboratory from the nest in a glass jar, which I have previously described, mentioning its occurrence on June 1st. The details are now given.

Towards the end of April I examined the nest at the bottom of the jar, and observed the appearance of perfect insects, some brown, others still white, but becoming brown in the course of a few days. After May 20th, suspecting that swarming would take place soon, I covered the vessel with a wider and taller glass bell-jar. Both were placed on a pane of glass,

and the jar was not completely closed, because the paper did not accurately fit its mouth.

On June 1st, about 9 a.m., I found a number of winged forms with a few soldiers and workers on the part of the sheet of glass which lay between the two jars; the poor little animals had taken advantage of the spaces left by the ill-fitting paper to emerge, and were then vainly trying to escape from the bell-jar. Nothing was disturbed, and twenty-four hours later no change had taken place, except that the winged forms were more numerous, and some were moribund.

I then decided to liberate them, and removing the bell-jar I put them by means of a quill pen into a receptacle containing suitable materials for a nest—but without success, for they all died in less than forty-eight hours. No more winged examples could be detected through the walls of the glass jar; it was replaced unopened on the pane of glass, and once more covered with the bell-jar. Twenty-four hours later a large number of larvæ and several soldiers were again found on the pane. They were then returned to the nest by means of a quill, and did not escape again.

The observation here recorded was made some years ago, and though imperfect is not wanting in significance.

Another swarm was observed on a May morning of the present year (1892). There happened to be a small level place in front of the holes from which the perfect insects issued, and on this they ran to and fro before taking wing. They were accompanied by soldiers and workers which had emerged into daylight, evidently to protect the swarm.

Several writers have recorded that black Termites, when ready to fly, perform certain movements which can be best followed by putting the insects on a sheet of paper; these are the so-called love passages, often described, and especially by Fritz Müller.

They are not exhibited by Calotermes, but may easily be observed in Termes lucifugus.

The majority of examples dispose themselves after the loss of their wings in pairs, one behind the other. More exactly,

the one in front attempts to run away from the other, which pursues it and palpates the extremity of its abdomen, and sometimes the sides as well. In some cases the pair is composed of a wingless individual in front and a winged one behind; or a male in front and a female behind; or the opposite; or both may be of the same sex, whether male or female.

If a few workers are put among the imagos, one of the latter may often be seen to pursue a worker in the same manner. And occasionally three examples, instead of merely a pair, may be seen, one following the other.

I believe that the meaning of these supposed amorous displays is entirely different from that usually assigned to them, and that the pursuer wishes to solicit the dejecta of the one pursued; this will be explained in the following chapter.

I have said that the adults lose their wings (the persistence of the squama being understood) (Pl. 17, fig. 12), and I must now explain more minutely how this occurs. Suppose that the wings of a specimen are accidentally allowed to touch the moist walls of the glass jar, they stick to it, and readily break off as soon as the owner tries to run away.

[The insects perform various movements on their own account in order to tear off the wings. I have seen one raise and lower them, and at the same time put the hind leg over them so as to hold them down to the surface on which it was standing. Another example got rid of them by violent fluttering; and a third, which had only one wing left, tried to tear it off at first by forcible flapping, and then succeeded by holding it firmly with one of the hind legs.]

It often happens that the imagos lose their wings while still in the nest, but they nevertheless abandon it, as do those of Calotermes.

In fact, the perfect insect has an imperious craving to quit the nest in which it develops.

Winged examples artificially enclosed in a corked tube

quickly gnaw through the cork and escape. This happens even if the wings have fallen off.

It will be recollected that the two sexes swarm at different times. This is demonstrated by—

1. The fact that all members of a swarm are found to be of the same sex.

2. The presence in many nests, late in or at the end of the swarm-period, of black winged forms, which are all males or all females only (by a rare exception a single male may be found to every twenty or thirty females), whereas nests in which the imagos are still white contain a male to every two or three females.

The convulsive movements spoken of under Calotermes are exhibited alike by Termes, and are common to all members of the colony except the newly born, and have the same significance. Moreover the soldier is able simultaneously to produce a special crepitus (creaking), which arises whenever the head is held horizontally during the act of quivering by friction between the hind margin of the occiput and the anterior margin of the pronotum. But whenever the head is held in the normal position during the act—that is, somewhat deflexed—no perceptible sound is produced, owing to the absence of friction.

The soldiers, therefore, possess two distinct modes of communication; and it is noticeable that those of Calotermes always hold the head obliquely deflexed when quivering and produce no sound.

I may add that this characteristic crepitus may be heard at very short intervals by applying the ear to a trunk containing a nest of Termites. This proves that the quivering motions are a constant feature in normal and undisturbed nests, in which they are therefore not employed to give indications of alarm or distress; and I conclude that, besides these significations, the convulsive movements must also have the value of ordinary speech; that they constitute, in short, a means of intercommunication. The same conclusion holds good for Calo-

termes; and I imagine that the quivering of both species produces a sound which is perceptible to the tympanal organ of the tibia, but is inaudible to the human ear.

Termites, moreover, may communicate by means of the antennæ. Thus, if a few are placed on a table, they usually arrange themselves in single files, which circle round the objects standing thereon; and, in such a case, if two Termites moving in opposite directions chance to meet, they reciprocally touch their antennæ and then continue each on its own course (vide also previous statements).

Tasks necessary for the common welfare, with a few exceptions, are undertaken by all the inmates of the colony; but the soldiers are unable to gnaw wood, owing to the great elongation of their mandibles.

Substitute or complemental royal forms have never been seen to prepare wood-meal, or to transport it, or ova, &c. Yet all these duties are carried out by the perfect insects with fully developed wings, before or after they have been shed. Newly-born larvæ may easily be found carrying about wood powder.

[The soldiers serve for defence, like those of Calotermes. Two soldiers, one a Termite, the other a Calotermite, were put together in a small glass vessel. They accidentally came into contact and began to fight. The Termite, having the advantage of great quickness in movement, whereas Calotermes is sluggish, bit off some of its enemy's legs, and was proceeding to further hostilities, when the other seized an opportune moment and cut its head off. On other occasions the soldiers of Calotermes tore the abdomen of the soldiers of Termes to pieces.

The soldiers' mandibles may appropriately be likened to a powerful pair of shears. Termite soldiers become formidable when put into one of the customary little nests of Calotermes deprived of soldiers, rapidly cutting off the antennæ of numerous examples, and biting them in various places. But if they are few in number, the Calotermites eventually reduce them to helplessness by shearing off their mandibles, and then pursue, tear, and kill them.

A fight is invariably provoked by putting soldiers of both species into a jar; if large larvæ or nymphs of Calotermes are introduced into a colony of Termes they are usually left alone by the soldiers, which probably fear them; whereas Calotermites (see p. 283) always kill any workers or nymphs of Termes which have been added to their nest. Termes soldiers fraternise, and do not fall out, even when taken from different nests.

If triturated wood, soldiers, workers, and young of Termes are put together in a jar, the soldiers are soon seen to post themselves on the top of the rubbish, evidently on guard.

Sometimes inmates of the same nest (soldiers and workers, or the latter inter se) come to blows, and wound each other ferociously in the thorax or abdomen, and do not stop unless others interfere to separate them. These internecine battles can be provoked, e. g. by overturning the contents of a nest, and are perhaps due to each individual imagining that his neighbour is the cause of the disturbance.

Termites shun the light, and prefer to collect in the darkest parts of a vessel.]

(*To be continued.*)

EXPLANATION OF PLATES 16—20,

Illustrating Professor B. Grassi's and Dr. A. Sandias's paper on "The Constitution and Development of the Society of Termites: Observations on their Habits; with Appendices on the Parasitic Protozoa of Termitidæ, and on the Embiidæ."

The first number after the explanation of each figure indicates the ocular, the second the objective of the microscope employed. Kor. = Koritska microscope, with the tube in. Hart. = Hartnack microscope, with the tube in. T. = Termes lucifugus. C. = Calotermes flavicollis.

Instead of the expression that a given individual possesses, e. g. seventeen, antennal joints, the abbreviation "with seventeen joints" is employed.

PLATE 16.

Calotermes flavicollis.

FIG. 1.—Small-headed larva, with twelve joints. The third, fourth, and fifth indistinct; the former not pilose; the fifth with short hairs (distinguishable with a higher amplification only).

FIG. 2.—Large-headed larva, with thirteen joints. The third short, and not pilose.

FIG. 3.—Small-headed larva, with sixteen joints. The third and fourth scarcely indicated, and not pilose. Wing-rudiments distinctly present, but very short, and visible only with higher amplification.

FIG. 4.—Nymph, with seventeen joints. The third pilose, the fourth not.

FIG. 5.—Large soldier.

FIG. 6.—Perfect insect, with fully developed wings.

FIG. 7.—True queen, in the fourth year of maturity.

FIG. 8.—Outline of a true king or queen, in the second year of maturity.

FIG. 9.—Outline of a true queen, in the third year of maturity.

FIG. 10.—Outline of a true king, in the fifth year of maturity.

FIG. 11.—Outline of the abdomen of a true queen, in the fifth year of maturity (drawn approximately to the same scale as Fig. 10).

FIG. 12.—Young substitute queen.

FIG. 13.—Outline of the abdomen of a substitute queen, in the third year of maturity (drawn to the same scale as Fig. 11).

FIG. 14.—Developing royal substitute form, with fifteen joints; the third the shortest, and not pilose.

FIG. 15.—Exuviæ of a developing substitute form.

FIG. 16.—Outline of the body of a small soldier (the antennæ are omitted).

FIG. 17.—Outlines of the hind angle of (*b*) the mesonotum and (*a*) the metanotum of a substitute queen, with very slight traces of the wing-outgrowths. 3, 4, Kor.

FIG. 18.—Outline of the right half of the meso- and metanotum of developing substitute form. The anterior wing-rudiment is torn off.

FIG. 19.—Antenna of a small soldier. 3, 4, Kor.

FIG. 20.—Base of a fifteen-jointed antenna. 3, 4, Kor.

FIG. 21.—The same in a different stage, but still fifteen-jointed.

FIG. 22.—The same after development of a sixteenth joint.

FIG. 23.—Ovary and oviduct of a soldier. 3, 4, Hart.

FIG. 24.—Posterior leg of a young nymph.

FIG. 25.—Old substitute queen, with wing-rudiments.

FIG. 26.—Half of the thoracic terga, exhibiting wing-rudiments, in a young soldier. 3, 5, Hart.

Termes lucifugus.

FIG. 27.—Brain of a worker, by transmitted light. 3, 5, Hart.

FIGS. 28 to 33.—Series of horizontal sections of the brain of a young nymph, to exhibit the fungiform bodies (interpreted as psychic centres). They are represented by the darker and more closely dotted portions (which possess small, deeply staining nuclei).

Fig. 28 represents the most superficial section, and is followed by the others in numerical order.

FIG. 34 represents, by way of comparison, a similar section through the brain of Embia, at the point where the fungiform bodies attain the maximum dimensions. *gl.* Retro-cerebral gland. [This gland of unknown function exists (only ?) in the nymph of the first form, the perfect insect, and the soldier. It eliminates a transparent secretion, which can be spirted out for some distance.]

PLATE 17.

Termes lucifugus.

FIG. 1.—Larva, with eleven joints, the head undifferentiated.

FIG. 2.—Large-headed larva, with twelve pilose joints.

FIG. 3.—Small-headed larva.

FIG. 4.—Small-headed larva, with fourteen joints, the fourth not pilose.

FIG. 5.—Diagram of a similar but large-headed larva. The hair-lines between 2 and 3, and between 4 and 5, apply to each of the two figures.

FIG. 6.—Larva similar to 4, but larger and with wing-rudiments.

FIG. 7.—Larva similar to 5, but equal in size to that of Fig. 6.

FIG. 8.—Anterior portion of a larva similar to that of Fig. 7, but with a somewhat larger head; probably a soldier larva.

FIG. 9.—Larva, with fifteen joints; the third alone not pilose, and with evident wing-rudiments.

FIG. 10.—Nymph, with long wing-pads.

FIG. 11.—Fully winged perfect insect.

FIG. 12.—Perfect insect after shedding the wings.

FIG. 13.—Adult worker.

FIG. 14.—Soldier.

FIG. 15.—Young wingless substitute queen.

FIG. 16.—Old wingless complementary queen.

FIG. 17.—Old complementary queen, with slight rudiments of wings.

FIG. 18.—The same, with more distinct rudiments.

FIG. 19.—Male nymph of the second form (March 1st).

FIG. 20.—Outline of a male nymph of the second form (April 11th).

FIG. 21.—Young complementary queen, derived from a nymph of the second form.

FIG. 22.—Thorax of a nymph of the second form, with the wings more developed than those of the example in Fig. 21.

FIG. 23.—Substitute queen, derived from a nymph of the first form.

FIG. 24.—Substitute queen, derived from a perfect insect; partly infuscate, and with the wings torn (the infuscation is not shown).

FIG. 25.—Posterior extremity of a very old substitute queen, without sign of wings.

Figs. 1 to 25 are all drawn by the camera lucida to an equal scale, with exception of Figs. 16, 17, and 21, which are somewhat more enlarged.

FIG. 26.—Pronotum of a worker. 3, 4, Kor.

FIG. 27.—Pronotum of a completely wingless substitute queen. 3, 4, Kor.

FIG. 28.—Antenna of a nymph of the second form. 3, 4, Kor.

FIG. 29.—Antenna of a complementary queen. 3, 4, Kor.

FIG. 30.—Base of a twelve-jointed antenna.

FIG. 31.—Base of a thirteen-jointed antenna.

FIG. 32.—Base of a fourteen-jointed antenna.

FIG. 33.—Base of a fifteen-jointed antenna.

FIG. 34.—Base of a sixteen-jointed antenna.

FIG. 35.—Base of another sixteen-jointed antenna.

FIG. 36.—Base of a seventeen-jointed antenna (nymph of the first form).

FIG. 37.—Base of an eighteen-jointed antenna (nymph of the first or second form).

The figures 30 to 37 are all copied by the microscope, 3, 4, Kor., with the tube drawn out.

FIG. 38.—Flattened tube constructed by T., and suspended from a plaster cornice. The lower end (to the right of the figure) was open; the upper end is broken.

FIG. 39.—A similar flattened tube—short, enlarged and flask-shaped. A small portion of the cornice to which it was suspended is represented.

FIG. 40.—Portion of a gallery formed by T. in the angle of a wall; seen from the inside.

PLATE 18.

Termes lucifugus.

FIG. 1.—Ovary of a perfect insect before loss of the wings. 3, 6, Kor.

FIG. 2.—Ovaries of a nymph of the second form. 3, 4, Kor.

FIG. 3.—Ovary of a very old complementary queen. The tubules are evidently atropied, and the spermatheca was empty. 1, 4, Kor. *Por. ant.* = anterior portion.

FIG. 4.—Left ovary of a nymph of the first form. 3, 4, Kor.

Fig. 5.—Testis of a perfect insect before loss of the wings. 3, 6, Kor. (Spermatozoa are present in the vas deferens.)

FIG. 6.—Testis of a nymph of the second form. 3, 4, Kor.

FIG. 7.—Testis of a nymph of the first form. 3, 4, Kor.

FIG. 8.—Testes, vasa deferentia, and vesicula seminalis (the two latter not containing spermatozoa) of a perfect insect before loss of the wings. 3, 4, Kor.

In the above eight figures, and in some on the following Plate, the efferent ducts are partly shown, in addition to the generative glands.

FIG. 9.—Developing spermatozoa, in the fresh state. The one indicated with the letter *a* is fully developed. 4, $\frac{1}{12}$ Kor.

FIG. 10.—Oviduct (*tu.*), uterine portion (*ut. ov.*), spermatheca (*spt.*), sebaceous (colleterial) glands (*gl. seb.*) of a complementary queen. 3, 4, Kor.

FIG. 11.—Portion of the intestine at the origin of the four Malpighian tubules in a newly-born larva. 3, 4, Kor.

FIG. 12.—Similar portion, with four large and four small tubules. 3, 4, Kor.

FIG. 13.—Superficial portion of a nest of T. constructed in a jar, with exit-holes and chimneys for swarming.

FIG. 14.—Portion of a termitarium found in a bench in the church Pesara.

FIG. 15.—Tubular gallery, similar to that of Fig. 39, Pl. 2, but not flask-shaped.

FIG. 16.—Portion of a partly excavated and partly built nest, found in a large cavity in the root of a cactus swarming with T.

FIG. 17.—Galleries constructed by T. kept in a glass jar; D-shaped, except the one projecting over the lip, which is tubular. The shading at the bottom indicates the rubbish which harboured the colony.

PLATE 19.

The left side of the plate refers to Calotermes flavicollis, except Fig. 6, which refers to Termes lucifugus; the right side refers to Embia.

LEFT SIDE (CALOTERMES).

FIG. 1.—Ovary and colleterial gland of a true queen in the second year of maturity. 3, 4, Kor.

FIG. 2.—Ovaries of a very bulky queen, enlarged about three diameters (the tubes do not actually lie in one plane as in the figure). *ext. ant.* = anterior extremity.

FIG. 3.—Colleterial glands of a true queen. 3, 4, Kor.

FIG. 4.—Left testis (*test.*), vas deferens (*con. def.*), and vesicula seminalis (*ves. sem.*) of a true king. 3, 6, Kor.

FIG. 5.—Testis of a substitute king, several years old. 3, 6, Kor.

FIG. 6.—Portion of the spermatheca, showing the ducts and orifices of the underlying glands (fresh). (Termes lucifugus.)

FIG. 7.—Salivary glands of a small larva. *res.* = reservoir. 3, 8, Kor.

FIG. 8.—Relations of the hinder part of the chylific ventricle and intestine. The former contains a blackish, the latter a yellowish detritus. Their junction is indicated by the insertion of the Malpighian tubules.

FIG. 9.—Stomodæum (*int. ant.*) and part of the chylific ventricle (*int. med.*). *inv.* = invagination of the former into the latter.

FIG. 10.—Tympanic organ in the fresh state. 3, $\frac{1}{12}$, Kor.

FIG. 11.—Tube-nest. Large portions of the glass are obscured by disgorged matter. The cork is riddled with burrows, and is represented separately on the right.

FIG. 12.—Spermatozoa from the spermatheca, in the fresh state. 5, $\frac{1}{12}$, Kor.

RIGHT SIDE (EMBIA).

FIG. 1.—Ventral ganglionic chain; L. 1 = anterior, L. 2 = middle, L. 3 = posterior leg.

FIG. 2.—Dorsal view of the tracheal system (the stigmata are numbered).

FIG. 3.—Alimentary canal. *gl. sal.* = salivary glands. *int. ant.* = œsophagus and proventriculus. *int. med.* = chylific ventricle. *int. post.* = intestine.

FIG. 4.—Ovarian tubes and oviducts (*ovd.*). *seg. med.* = segment médiaire (the successive abdominal segments are numbered).

FIG. 5.—Male generative organs.

FIG. 6.—Posterior extremity of the male. *proc. dext.* = right, *proc. sin.* = left apophysis. *cer. dext.* = right cercus.

FIG. 7.—Labium and labial palpus of one side.

FIG. 8.—Maxillary lobes and palpus.

FIG. 9.—Anterior tarsus (seen obliquely from the side).

FIG. 10.—Middle tarsus (idem).

FIG. 11.—Posterior tarsus (idem).

PLATE 20.

Parasitic Protozoa of Termitidæ.

The figures are all drawn with a Koritska microscope, ocular 5, objective $\frac{1}{16}$, Leitz. The dotted lines represent the continuation of the unbroken lines on the remote face.

FIG. 1.—Trichonympha agilis, in optical section, nearly corresponding with the middle plane of the body.

FIG. 2.—The same, at a somewhat different level.

FIG. 3.—The same, in a superficial plane.

FIG. 4.—The same, partly schematic, to show the arrangement of the flagella.

FIG. 5.—The same, to give an idea of the complicated arrangement of the spicules in some examples.

FIG. 6.—Joenia annectens.

FIG. 7.—Idem.

FIG. 8.—Idem.

FIG. 9.—Endoskeleton and nucleus of a very large example of Joenia in optical section.

FIG. 10.—Microjoenia hexamitoides.

FIG. 11.—Dinenympha gracilis.

FIG. 12.—Idem.

FIG. 13.—Idem.

FIG. 14.—Idem.

FIG. 15.—Idem.

FIG. 16.—The same, with spirilla attached to one extremity.

FIG. 17.—The same, covered with spirilla.

FIG. 18.—Pyrsonympha flagellata (the majority of the flagella are omitted).

FIG. 19.—The same, in superficial view.

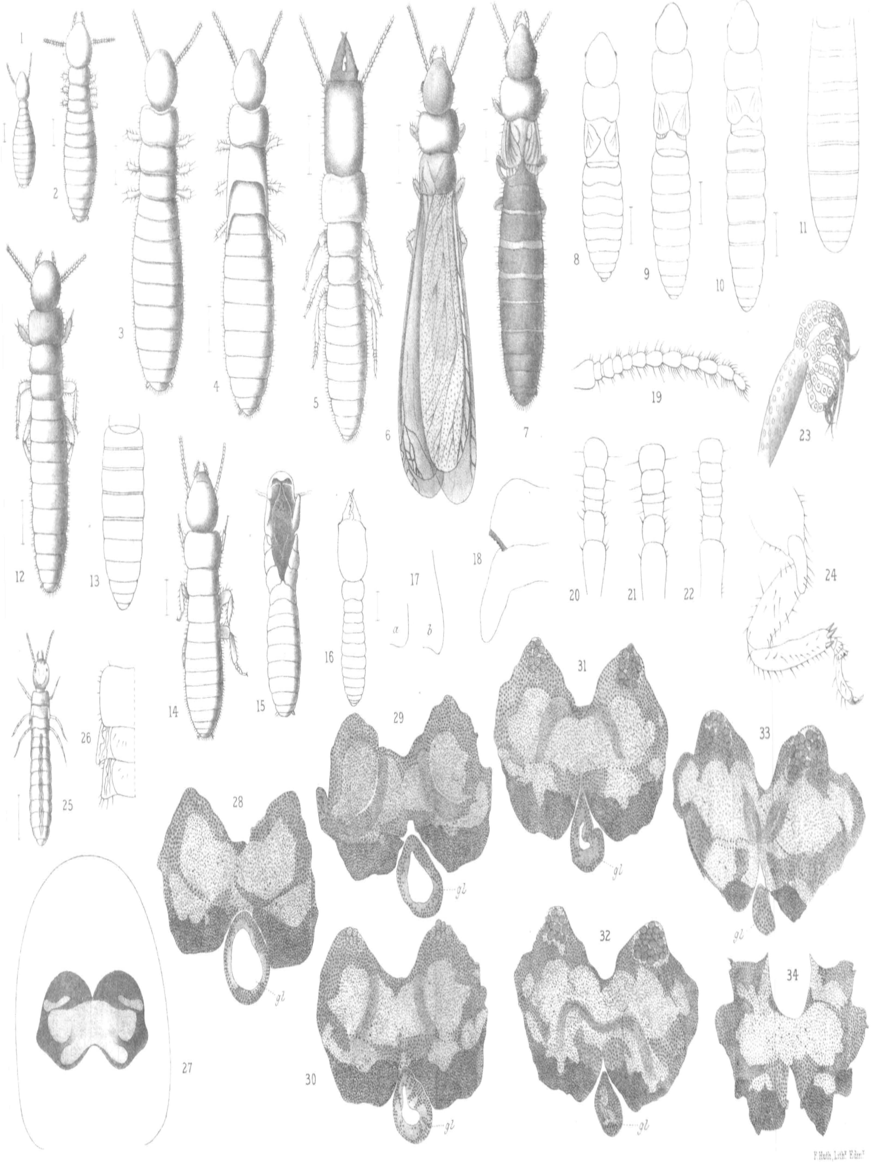
FIG. 20.—The same, exhibiting the nucleus and rodlets.

FIG. 21.—Holomastigotes elongatum (the majority of the flagella are omitted).

FIG. 22.—The same, in superficial view.

FIG. 23.—Plan of the lines of origin of the flagella on both faces of Holomastigotes elongatum.

FIG. 24.—The same, in another individual.



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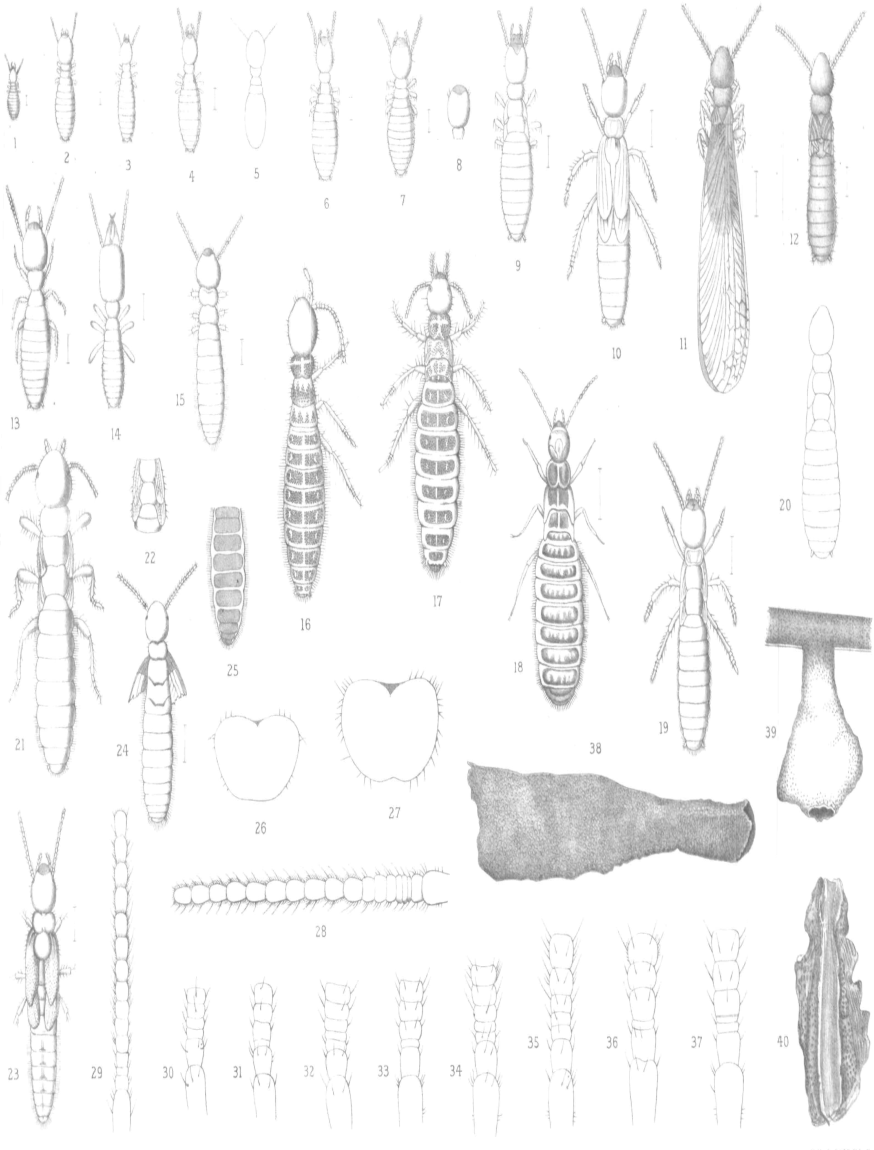

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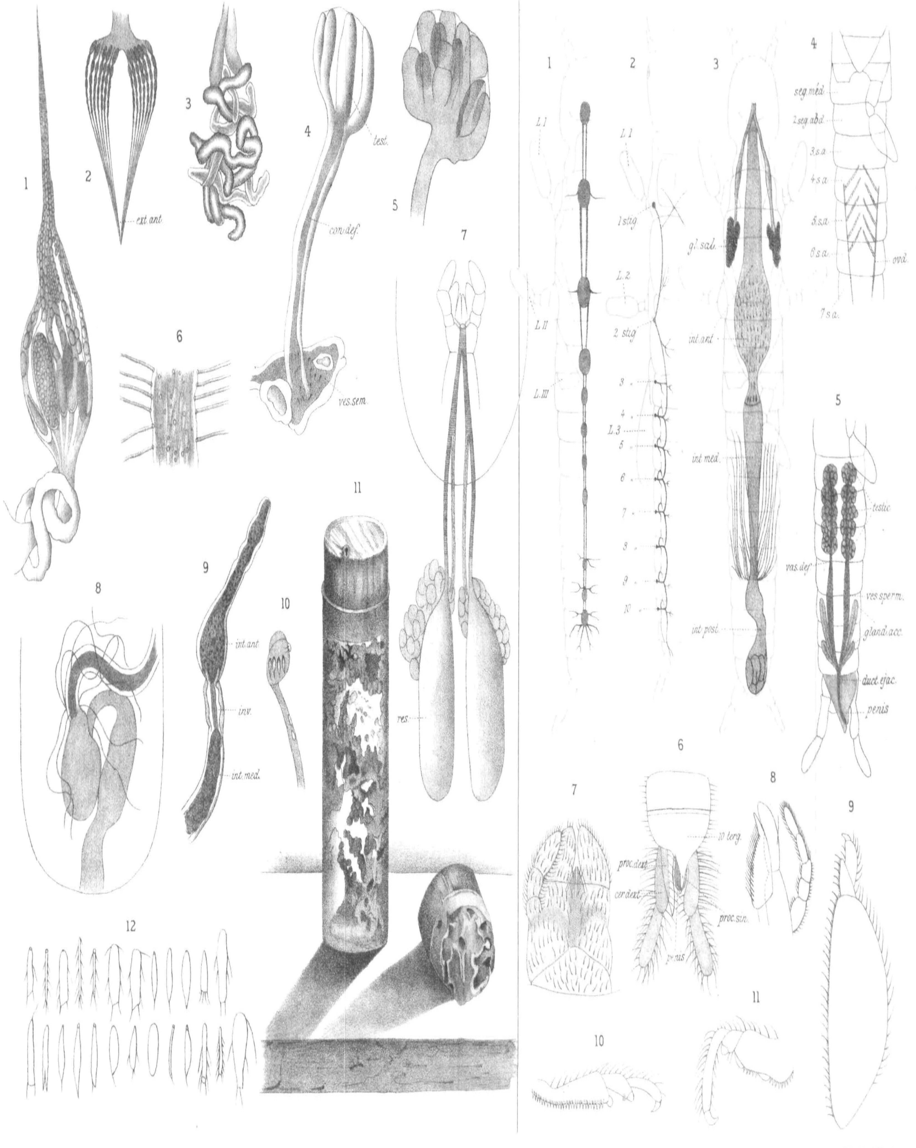

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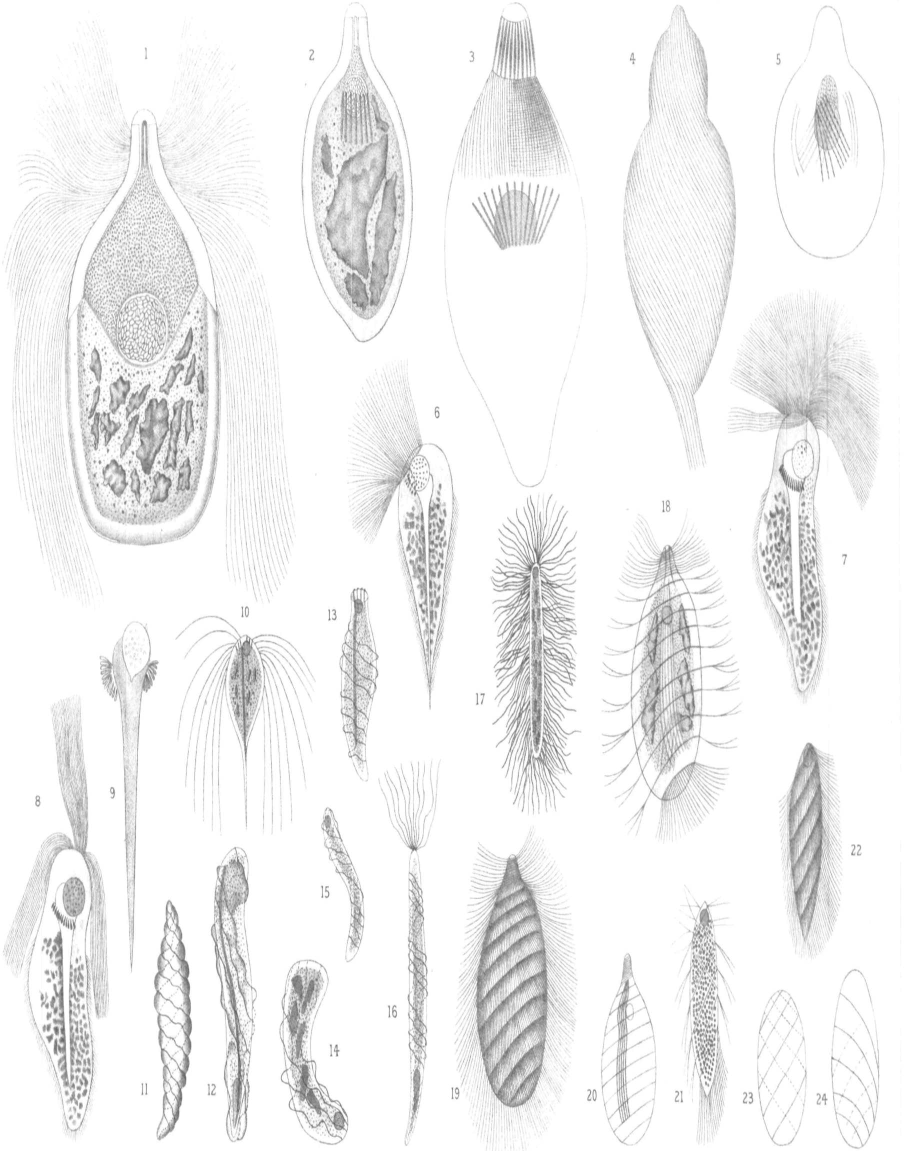

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